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HILDRETH, KATHLEEN. The Effects of Two Isometric Exercise Programs Upon Cardiovascular Efficiency and Selected Anthropometric Girth Measurements. (1967) Directed by: Dr. Frank Pleasants. pp.135.

The purpose of this study was to determine the effects of two different programs of isometric exercise upon cardiovascular efficiency and selected anthropometric girth measurements: upper arm, waist, hips, thigh, and calf.

Subjects for the study were forty-four college women enrolled in recreational sports classes at the University of North Carolina at Greensboro during the spring semester of 1967. The subjects were divided into three groups: Control who did not exercise, Experimental 1 who used a six-second contraction, and Experimental 2 who used a twelve-second contraction. The experimental groups used a program of seven selected isometric exercises daily for five weeks. Each subject was administered the Skubic-Hodgkins Cardiovascular Efficiency Test for College Women and girth measurements were taken at the beginning and end of the experiment.

From the results of the analysis of variance and "t" tests, it was concluded that:

1. An isometric exercise program, using either a six-second or a twelve-second contraction, was effective in increasing cardiovascular efficiency.
2. In comparison with the Control Group, an isometric exercise program using a six-second contraction effectively reduced girth in the upper arm, waist, hips, thigh, and calf body regions.
3. In comparison with the Control Group, an isometric exercise program using a twelve-second contraction effectively reduced girth in the hips, thigh, and calf body regions. 1967
4. An isometric exercise program, using either a six-second or a twelve-second contraction, effectively reduced girth of the upper arm, waist, hips, thigh, and calf regions.
5. The six-second contraction was as effective or more effective than the twelve-second contraction and thus would be recommended in the sake of exercise-time expenditure.

Frank Pleasants
Adviser

APPROVAL SHEET

This thesis has been approved by the following

**THE EFFECTS OF TWO ISOMETRIC EXERCISE PROGRAMS
UPON CARDIOVASCULAR EFFICIENCY AND SELECTED
ANTHROPOMETRIC GIRTH MEASUREMENTS**

by

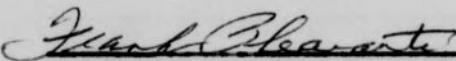
Kathleen Hildreth

**A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Science in Physical Education**

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CHAPTER I

INTRODUCTION

If an individual is to adequately meet the stresses and demands of daily living, which are becoming progressively greater with the ever-increasing pace of life, an optimum fitness level is vital to each person. In our "push-button" society, however, it is difficult to exercise vigorously every day--a necessity for the development and maintenance of one's fitness. Some of the problems and inconveniences involved with exercising include the scheduling of the necessary time, locating sufficient space and equipment, changing to suitable clothing, and showering afterward. Unfortunately, these considerations are of enough consequence that many people do not exercise adequately.

Since isotonic exercise programs involve these inconveniences, an alternative may be isometric exercise. A program of isometric exercise costs less, requires few facilities and equipment, takes little time, leads to outstanding results in terms of strength development and maintenance, and has been proven safe to use. (64)

With the administrative advantages of isometric exercise, why is this type of exercise not advocated more often by authorities in the area of fitness and

exercise? If this type of exercise would ensure a higher percentage of participation and a higher fitness level nationally, why is it not being promoted?

An answer to these questions appears to be the important consideration of the cardiovascular system. Most of the authorities in the area of physical fitness seem to be agreed that isometric exercise does not develop the body's cardiovascular efficiency--one of the most important facets of physical fitness:

Physical fitness is more than muscular strength or even muscular endurance. A third essential component is pulmonary-circulatory endurance. Thus any exercise program limited solely to strength development is deficient as an adequate approach to physical fitness. (23:58)

Bender, an exercise expert, stated that three types of conditioning are necessary in physical education and athletics: cardiovascular efficiency, muscular strength, and muscular endurance. Of these three, "isometrics can develop only strength." (39:21)

Very recently, however, there has been some evidence indicating that perhaps isometric exercise does contribute to the development of cardiovascular efficiency. This is an area into which further investigation is necessary, and this study will attempt to discover the effects of a systematic program of isometric exercise upon cardiovascular efficiency.

A motivation for exercise that cannot be overlooked is feminine concern about a slim figure. For years part of the successful prescription for figure control has been exercise--exercise of the active isotonic type. Can isometric exercise prove just as successful in girth reduction? This investigation will attempt to answer this still uncertain and relatively unexplored relationship between isometric exercise and girth change.

CHAPTER II

STATEMENT OF PROBLEM

The twofold purpose of the study was to determine the effects of selected isometric exercises on (1) cardiovascular efficiency and (2) selected anthropometric measurements of college women.

I. DELIMITATIONS

This study was limited to the following areas:

1. The study was limited to college women enrolled in three recreational sports classes at The University of North Carolina at Greensboro during the spring semester of 1967.
2. The study was limited to two different isometric exercise programs which were five weeks in length, or a total of thirty-five exercise periods.
3. The cardiovascular efficiency measurement was limited to the Skubic-Hodgkins revision of the Harvard Step Test.
4. The anthropometric girth measurements were limited to those of the upper arm, waist, hips, thigh, and calf body regions.

II. DEFINITIONS

Anthropometric measurements. Anthropometric measurements are defined as "objective measurements of structures and of functions of the body." (19:345)
This study involved girth measurements of the upper arm, hips, thigh, and calf body regions.

Cardiovascular efficiency. Cardiovascular efficiency refers to "optimum adaptability of the body to do and recover rapidly and completely from hard work." (131)
For the purposes of this study, the term was used interchangeably with cardiorespiratory endurance, circulatory endurance, pulmonary-circulatory endurance, cardiovascular endurance, and cardiorespiratory efficiency.

Fitness. Fitness is defined as the "state which characterizes the degree to which a person is able to function." (3:124)

Heart rate. Heart rate refers to the number of times the heart beats each minute. In this study the term was used interchangeably with pulse rate.

Isometric exercise. Isometric exercise means "vigorous muscle contraction sustained for a brief period without producing movement." (70:43)

Isotonic exercise. Isotonic exercise means "a contraction in which a muscle shortens against a load, resulting in movement and the performance of work." (20:302)

CHAPTER III

REVIEW OF LITERATURE

Exercise of some type is essential for the development and maintenance of one's fitness. The type of exercise program which will result in the optimum fitness level is a question yet to be satisfactorily answered by the research. The present study was an attempt in this direction.

This particular study was concerned with isometric exercise and its effect on cardiovascular fitness. Two groups of college women exercised daily for five weeks, and the change in their cardiovascular efficiency was noted. The aesthetic aspect of exercise, however, was also considered since a woman is, of course, concerned about her figure. The effects of the isometric exercise program on selected anthropometric girth measurements were observed also.

In order to develop an isometric exercise program and select the appropriate measures to be used in the study, research in the following areas was investigated: (1) isometric exercise, (2) cardiovascular endurance, (3) cardiovascular measures, and (4) anthropometric measurements.

I. ISOMETRIC EXERCISE

In recent years isometric exercise has been a widely-discussed subject, not only within the physical education profession but also publicly. Exercise "faddists" saw immediately the commercial appeal of isometric exercise and quickly took advantage of its time-saving benefits. As with other types of exercise, there are many differences of opinion and many controversies related to isometric exercise. Since this study dealt primarily with the use of isometric exercise, some of the controversial issues were reviewed.

Physiologists, researchers, and physical educators have found it very difficult to agree on exactly what isometric exercise is and how it differs from isotonic exercise. Bender defined isometrics as "muscle contractions where the subject exerts force against a resistance which doesn't move" and that isotonics are the same except that a moving resistance is encountered. (39:21)

Steinhaus disagreed, stating that:

An isotonic contraction is one in which the tension in the muscle remains constant. Shortening or lengthening contractions are rarely isotonic because of the consistently changing length of the force and resistance arms in the lever system of the moving bones. Isotonic is in no sense the opposite of isometric contraction. In fact isometric contractions are probably the only ones in which a true isotonic state is often attained. (29:86)

Others have defined an isometric contraction as "static application of force against an immovable object with maximum force being applied for a specified period of time" (133:10); a contraction whose "length does not change" (15:10); "muscular contraction without movement" (64:58); "vigorous muscular contraction sustained for a brief period without producing movement" (70:43); "muscular contraction in which the individual exerts force against an immovable object" (35:3); or a "contraction in which a muscle is unable to shorten, the total tension developed eventually dissipated as heat. No movement is produced and no work is performed" (20:302).

It seemed generally agreed, however, that an isometric contraction was a muscular contraction against a resistance where no movement occurred, whereas an isotonic exercise involved body movement and was illustrated by the exercises traditionally carried out in our physical education programs. The area of isometric exercise was reviewed within this frame of reference.

How did the current publicity about isometric exercise begin? In 1953 at the Max Planck Institut (sic) two German scientists, Erich Müller and Theodore Hettinger (93), carried on an eighteen-month research project of seventy-one experiments on nine male subjects in an attempt to discover the effects of isometric contraction. They varied the exercise programs in terms of the number

of exercise bouts each day, the intensity of the strength load, and the length of the individual contractions.

Results of this pioneering study indicated that:

1. One six-second practice period once a day results in as great a strength increase as longer periods and more frequent periods of exercise.
2. Muscular strength increases more rapidly with increasing intensity up to two-thirds maximum strength but the increase beyond this point is of no benefit in terms of strength development.
3. Muscular strength increases an average of five per cent per week at one-half maximum strength level. (93:117)

Much skepticism was immediately raised. Were Hettinger and Müller's results reliable and valid? They had concentrated their research on the arm muscles. Would isometric exercise applied to the other areas of the body yield similar strength increases? Is one six-second contraction really the most effective? If strength increased this rapidly, what would be the rate of strength loss? Does strength development result in muscle hypertrophy or is the girth decreased? With the startling results such as those announced by the two Germans, it was inevitable that there would be many more questions to be answered and that much more research in this area needed to be undertaken.

Additional research was carried on in order to answer these questions, and generally there was agreement

that isometric exercise indeed did effect a rapid strength gain and that Hettinger and Müller's findings were justified, at least on this point. The results, however, indicated that there was little agreement on the questions of the most effective exercise program; the optimum intensity, frequency, and duration of the contractions; and the benefits of isometric exercise beyond the development of increased strength. These questions provided the controversial "meat" on which the researchers are still chewing. Since this study was concerned with the effects of isometric exercise, the writer investigated the current theories as indicated by research.

The major portion of the research in isometric exercise has been concerned with increases in strength, and, as stated above, there was general agreement that isometric exercise resulted in the development of increased strength.

Dennison and associates (57) compared a fifteen-minute isometric exercise group with a forty-five minute weight-training group on the basis of chin-ups, dips, and an Arm Strength Index. The results indicated that the isometric exercise group's improvement in the chin-ups and the dips was significant at the .05 level of confidence. Although the weight-training group also increased in strength, the implications in terms of exercise time were quite significant.

Barick (96) tested and retested three groups of college men on the cable tensiometer once each week. One experimental group did isometric exercises for the wrists six seconds each day for a four-week duration while another experimental group exercised more frequently each day. The findings generally confirmed Hettinger and Müller's results that brief periods of exercise at two-thirds strength load were as effective as more frequently repeated exercise bouts at full strength.

Mathews and Kruse (81) used 120 male college students in an attempt to discover the best isometric exercise program in terms of frequency and to compare with the isotonic group exercising on the Kelso-Hellenbrandt ergometer. Maximum effort was exerted on three consecutive six-second pulls on a strap for two, three, four, or five times each week for four weeks. It was concluded that isometrics caused a greater number of subjects to gain significantly in strength and that exercising five days each week was the most beneficial in terms of strength gains. Many other studies have confirmed the above findings.

What is the best or the optimum intensity of a contraction? DeVries reported that the "rate of strength gain approximately doubles when maximal contraction is used instead of two-thirds of maximum." (10:308)

Richey said that athletes require three or four

seconds to reach the desired effort and that in order to obtain the desired results, maximum force should be exerted for nine to twelve seconds. "Only maximum contraction brought about by considerable force will develop the strongest muscles desired in athletic ability." (100:48)

Steinhaus stated that a maximum contraction held for one second each day will make no difference but that a maximum contraction held for four to six seconds and repeated from five to ten times each day will increase the rate of growth as well as the end strength. He also admitted, however, that whether the longer duration or the increase in repetition was the more crucial factor has not been settled. (29:136)

In a study by Taylor (116) four groups were experimented with under differing strength loads and differing durations. Group I pulled maximally for twelve seconds, Group II pulled maximally for six seconds, Group III pulled at two-thirds of maximum for twelve seconds, and Group IV pulled at two-thirds of maximum for six seconds. He reported no significant differences in these four groups. Higdon stated, however, that "in order to obtain the strength-building benefits of isometric exercise, you must reach close to a maximum contraction." (64:66)

Perhaps the greatest claims made by the original isometric studies were the seemingly fantastic rates of

strength increase. A 5 per cent increase weekly was reported as the result of short duration, once-a-day contractions. (93:117)

After their original 1953 statements that the strength would increase at the rate of 5 per cent each week, Hettinger and Müller continued studying this aspect of their findings and at several times issued revisions of this figure. In 1958 Hettinger reported a 3.3 per cent increase, and in 1961 he stated that the increase was but 1.8 per cent. Their most recent views indicated that:

There is no regular 5% increase per week. The rate of increase varies with the gap between the muscle's present strength and the maximum or end-strength attainable by a given training program. When initial strength is less than 60% of the end strength, the gains are approximately 11% of the end each week. These gains per week become smaller and smaller as the muscle approaches its end strength. When strength reaches 80% of the end strength this weekly increase will be about 8.6%, at 85% about 7.5%, at 90% about 5.6%, at 95% about 3.5%, and at 98% about 2.0%. . . . The greater the strength of a contraction is in relation to the present strength of a muscle the faster will the muscle strength grow. (29:136)

Perkins felt that the average person, or one who was not accustomed to physical activity, can expect a strength increase of approximately 5 per cent per week up to a maximum of twenty weeks after which the rate declines. This means that "in a twenty-week period the strength of a particular muscle or muscle group can be doubled." (133:81)

But if strength is increased this rapidly, how long could it be retained? Is it decreased just as rapidly if the exercise is not continued? In 1954 Hettinger and Müller reported that if strength was increased at the rate of 5 per cent each week, and if training was discontinued after a few weeks, strength decreased similarly at the rate of 5 per cent each week back to the original level. They also stated, however, that once a muscle is trained to be 50 per cent stronger than its original level, this strength may be retained indefinitely at this level by two and perhaps only one maximal contraction per week. (29:136)

Further research indicated that after a 50 per cent strength increase the strength was retained at that level for twelve weeks with absolutely no special activity other than the normal daily routine. In the next twenty-eight weeks of no exercise, "strength was still far from having returned to the level it started from at the beginning of the experiment." (29:136)

Rarick (96) concluded that strength was retained longer when the isometric contractions were performed maximally and were performed more frequently.

Equally important in muscular development is the problem of increasing the endurance of the muscle, or the "capacity of a muscle group to maintain or repeatedly develop a certain degree of tension." (114:193) Relatively

few studies in the area of muscular endurance and its relationship to isometric exercise were found in the literature, indicating a need for this area of research.

Howell, Kimoto, and Morford (67) studied muscular endurance with three groups that exercised twice each week for eight weeks. One group lifted weights, one did isometric exercises, and the third served as a control group. On the basis of testing with the bicycle ergometer, both the weight-lifting group and the isometric exercise group showed an increase in muscular endurance, significant at the .01 level. It was thus concluded that muscular endurance can be developed by isometric exercise methods. Other studies were in general agreement with these findings. (57; 88; 114)

II. CARDIOVASCULAR ENDURANCE

When speaking of endurance, it is necessary to differentiate semantically between cardiovascular endurance and muscular endurance. It must be understood that muscular endurance and cardiovascular endurance, referred to interchangeably as cardio-respiratory, circulatory, and circulo-respiratory endurance, appear to be related:

The factors of strength, muscular endurance, and the efficiency of the heart and lungs are interdependent. Muscular endurance is a combination of strength and muscular endurance and circulorespiratory endurance is a combination of all three factors. (19:116)

Cardiovascular endurance is:

. . . a function of the muscular strength and the muscular endurance of the skeletal muscles and the cardiac muscle, the efficiency of the lungs, and the responses of the circulatory system to stimulation by the sympathetic nervous system. (6:95)

Willgoose stated that cardiovascular endurance is a separate variable in physical fitness--a "kind of physiological fitness demonstrated through an adjustment of the heart and lungs to prolonged physical exertion." (34:105-106) He also indicated, however, that cardiovascular endurance is related to muscular endurance:

Cardiorespiratory endurance involves continued activity of the entire organism, during which major adjustments of the circulatory and respiratory systems are necessary, as in running, swimming, climbing, and the like. This form of endurance is not only dependent upon the strength of the muscles involved but must rely greatly on the effective functioning of the circulatory system. (6:95)

Muscular endurance, on the other hand, is the capacity for long continued sub-maximal contractions, where a sufficient number of muscle groups are used with enough intensity and long enough duration to place a demand on the circulatory and respiratory systems. (6:232; 34:105) It can thus be seen that cardiovascular endurance and muscular endurance cannot be entirely separated or viewed as distinct variables independent of one another.

Cardiovascular endurance is affected by many

variables. Morehouse and Miller suggested that a factor which affects endurance is the amount of fat in and on the body. (20:238) "Since fat increases the load a worker must move with each motion, it becomes a limiting factor in endurance." They also stated that the:

. . . strength of the working muscles is a limiting factor in endurance. The load easily carried by the strong muscles may quickly exhaust the weak ones. When strong muscles lift a comparatively light load, only a relatively few fibers need to be brought into play. As these become fatigued, their threshold of irritability is raised and they fail to respond to the stimuli. The stimuli then arouse fresh fibers and they take over the work while the fatigued fibers recuperate in order to resume the burden later on if needed. (20:238)

Endurance for moderate activity is dependent upon the availability and utilization of the phosphocreatine and fuels such as sugar. For more strenuous work the endurance is affected by the ability of the body to maintain its oxygen supply and to dispose of its lactic acid and carbon dioxide accumulation and by the effective functioning of the heart, lungs, kidneys, and other organs that sustain activity. (20:237) The oxygen supply is extremely vital to endurance.

If a muscle is supplied with plenty of oxygen, it does not become fatigued since oxygen can come to the muscles only via the blood stream. It is obvious that any adjustment that increases the amount of blood going to the exercising muscles will thereby postpone

fatigue and by so doing increase endurance.
(29:90)

The trained person with great endurance was characterized by:

. . . (1) extensive increase in capillary irrigation of muscle, (2) a stronger heart, (3) extra oxygen-carrying capacity of the blood, (4) extra food readiness, (5) greater efficiency of the conversion of oxygen and food to energy, (6) less oxygen need per unit of work, (7) better response of muscle to stimuli, (8) better temperature controls.
(29:89)

Willgoose concurred that:

With muscle training the stroke volume of the heart improves to a point where more blood is pumped per stroke with fewer strokes per minute than in an untrained or unconditioned person. In short the total cardiac output is increased. Furthermore the rate of lactic acid formation is lowered in a trained person, resulting in a lower blood-lactate concentration. There is also a slower rate of breathing and a corresponding economy in respiration. (34:106)

Morehouse and Miller emphasized that at rest there are no noticeable physiological differences between an athlete and a non-athlete but that when working, the differences soon appear especially if the work is strenuous. (20:102)

Cardiovascular Endurance Measures

To separate organic condition from the skill of performance is to understand the organic capacity of the individual and the conditioning requirement of the exercise. (25:73)

The area of cardiovascular testing has not progressed a long way since 1859 when Mosso experimented with the effects of exercising a muscle on an ergometer. (16:187) As Mathews has pointed out, the physiologists still have not devised a completely satisfactory test for the appraisal of cardiovascular fitness. (16:187)

How to measure endurance has become the center of much controversy. Scott said that "endurance is the most difficult aspect of fitness to measure" and that it can be evaluated by measuring the subject's ability to maintain activity at maximum speed for a short period of time or to stay active for a longer period of time at a slower rate. (27:303)

"Probably the most valid test of cardiovascular condition is the measurement of oxygen intake during exercise." (16:189) It must be acknowledged, however, that its practical use is rather limited due to the expensive equipment and the necessity for trained technicians and cooperative subjects.

Clarke stated that the factors most frequently measured in endurance testing, particularly cardiovascular testing, are pulse rate at rest, after exercise, and after rest following exercise; and systolic, diastolic, and venous pressures. (6:95) Brouha and Radford felt that the heart rate:

. . . as a single factor accurately depicts

the cardiovascular adjustment to activity and that the estimate of the capacity to do muscular work should be based on the subject's actual ability to perform it and on the speed of the recovery after exercise. (14:205)

Generally, cardiovascular or cardiorespiratory measures attempt to "appraise heart-lung efficiency during or after some specified amount of physical exercise." (34:106) Numerous tests have been devised to evaluate cardiovascular endurance, and some of these are briefly described below.

Balke Treadmill Test. (16:191) On the Balke-devised treadmill the subject walks at a constant speed until his heart rate reaches 180 beats per minute, T_{180} , as measured by an electrocardiograph. The slope of the treadmill is increased each minute. A percentage score is calculated in terms of the minutes of sustained walking required to reach the heart rate of T_{180} .

$$\% \text{ score} = \frac{W_1}{W_2} \times \frac{k_1}{k_2} \times 100$$

W_1 = work in final minute

W_2 = body weight

k_1 = group mean body weight

k_2 = average work in final minute

Nagle and Bedeck (94) reported that using an all-out treadmill run as a criterion measure, the T_{180} heart-rate

test appeared to be a valid test of circulorespiratory capacity.

Barach Energy Index. (38) In an attempt to measure the energy of the circulatory system in terms of blood output, the Barach Energy Index measures energy expended by the heart by utilizing the systolic and diastolic blood pressure and the pulse rate per minute. The energy index is calculated by the following formula:

$$\frac{\text{Systolic pressure} + \text{diastolic pressure}}{100} \times \text{pulse rate}$$

Crampton Blood Ptosis Test. (6:97; 52) One of the earlier tests was the Crampton Blood Ptosis Test. Based on changes in the heart rate and the systolic blood pressure upon standing to reclining position, Crampton's aim was to find a "test of general physical condition that could be used in growth and development studies of youth."

(34:111) The test fails to differentiate between persons in fairly good physical condition, but it is a useful measure in evaluating those in very poor physical condition. (19:291; 34:112)

Schneider Test. (108) This test tries to combine the measurement of the standing pulse rate and the blood pressure with the measurement of the effects of exercise on the cardiovascular system. (16:204) The test involves the taking of a resting pulse rate and a reclining systolic

pressure followed by a mild step-up exercise, five times in fifteen seconds on an eighteen and one-half inch bench. Post-exercise pulse rate and systolic pressure are recorded both immediately after the cessation of exercise and after a two-minute recovery period. As Schneider stated:

A performance test requires the subject to do something in which the amount and character of the work is regarded as a measure of fitness. These should be abandoned since none of them yields results that do not require interpretation and correction for interfering factors such as knack, practice, alertness, interest, willingness to undergo discomfort and effort, cooperation and incentive. (108:508)

The test was reported as not very discriminating, but it will differentiate the extremes. (34:112)

McCurdy-Larson Test of Organic Efficiency. (16; 89)

The McCurdy-Larson Test of Organic Efficiency is designed to estimate the functional efficiency of the cardio-respiratory system of college men. (6:97) The five test elements are the following: (1) sitting diastolic blood pressure, (2) breath-holding twenty seconds after a standard step-up exercise, (3) difference between standing normal pulse rate and the pulse rate two minutes after exercise, (4) sitting blood pressure, and (5) standing pulse pressure. Larson (75) later shortened the test battery to sitting diastolic pressure, breath-holding after exercise, and standing pulse pressure.

The Foster Test. (16; 131) The Foster Test is based on the principle that the increase in the frequency of the heart beat is directly proportional to the intensity of the exercise and that the pulse recovery rate indicates the subject's physical condition. If the pulse rate does not increase proportionally, it is concluded that the subject is in poor condition. The test consists of a pulse reading taken while the subject is in standing position, followed by the subject running in place for fifteen seconds at the rate of 180 steps per minute. Immediately after the exercise ceases, the five-second pulse reading is taken and is multiplied by twelve to give the minute rate. Then after forty-five seconds of standing the pulse rate is again taken. Foster feels that his test "has the advantage of being simple, fairly accessible, and positive, and requiring only the use of the stop watch and the ability on the part of the observer to record pulse accurately." (16:196) Willgoose stated that this test is not reliable, however, since the standardization and control is not thorough, but that it could be of some value in screening procedures. (34:110)

Tuttle Pulse Ratio Test. (6:97) This test measures the effect of thirteen-inch bench stepping upon the heart and the recovery rate of the heart. The ratio is calculated by dividing the post-exercise pulse rate for two minutes

by the resting pulse for one minute. (118) The index is found by the application of this formula (16:205):

$$100 \times \frac{\text{Number of steps for 2.5 pulse ratio}}{50}$$

Woodall Test. (137) Woodall's cardiovascular test was specifically designed to measure the fitness of girls. After the reclining pulse rate was counted, the subjects ran for thirty seconds on a running board at a pace set for them by an electric metronome. A fifteen-second pulse rate reading was recorded immediately after the exercise. The subject lay down, and fifteen-second pulse readings were taken at thirty-second intervals for the next two minutes. The lower the difference between the resting pulse rate and the resting pulse rate taken thirty seconds after exercise, the better the cardiovascular condition of the subject.

Cameron Heartometer. (9) This machine records the brachial artery pulse and is a good indicator of cardiovascular condition and of relative amounts of fatigue. The machine, however, is not practical for widespread use in the schools, and training is necessary for the analysis and interpretation of the scores. (34:110) Cureton stated that the Cameron Heartometer can be used to "show differences between normal individuals in present cardiovascular condition and relative amounts of cardiovascular fatigue." (8:232) The heartometer differs from

the electrocardiograph in that it records mechanical pressure variations rather than electrical variations. (34:110)

Carlson Fatigue Test. (44) The Carlson Fatigue Test involves running in place in order to put physiological stress upon the individual being tested. The subject runs for ten seconds, rests for ten seconds, and repeats this ten times. Pulse rates are recorded before the exercise, ten seconds after the exercise has stopped, two minutes after the exercise, four minutes after the exercise, and six minutes after the exercise. Administratively this test has many advantages since it can be given anywhere, any time, to a large group, and with a minimum of equipment. In addition it has been found to be of value as a conditioning method as well as an evaluation instrument. (44)

Harvard Step Test. Brouha and his associates (41) developed the Harvard Step Test while working at the Harvard Fatigue Laboratory in the 1940's. Brouha stated that the purpose of this test was to "measure the general capacity of the body, in particular the cardiovascular system, to adapt itself to hard work and to recover from what it has done." (41:31)

Some disagreement was found concerning the value of the step test as a measure of endurance and whether or not it was a reliable and valid measuring instrument.

Clarke found that the step test differentiated between athletes and non-athletes but did not correlate highly with endurance criteria. (6:192) McCloy and Young (19) indicated that the step tests were:

. . . well-validated and measure a sort of general endurance; that is, they do not measure strength, or muscular endurance or cardio-respiratory endurance in any special way. The item is what most physical educators mean when they say "he seems to be in pretty good shape." (19:304)

Generally, however, investigators seemed to be satisfied that step tests presented a reliable measure of an individual's fitness. Cook and Wherry (51) felt that the final score of the Harvard Step Test was less affected by factors that are due to chance than are other cardiovascular tests.

The test consists of stepping on and off a twenty-inch bench for a period of time as long as five minutes at a cadence of thirty steps per minute. After the cessation of exercise, three thirty-second pulse readings are recorded: from one minute to one and one-half minutes, from two minutes to two and one-half minutes, and from three minutes to three and one-half minutes. The cardiovascular efficiency index is calculated from the following formula:

$$\text{Efficiency Index} = \frac{\text{Duration of exercise (sec.)} \times 100}{2 \times \text{sum of pulse counts in recovery}}$$

At the Harvard Fatigue Laboratory, Johnson and

Robinson developed a shortened form of the Harvard Step Test in order to save time in the test administration. (26:270) This test involved only one thirty-second pulse reading taken from one minute to one and one-half minutes after exercise. The following was used to find the efficiency index:

$$\text{Efficiency Index} = \frac{\text{Duration of exercise (sec.)} \times 100}{5.5 \times \text{pulse rate from 60-90 sec.}}$$

An efficiency index of 80 or above was considered very good, and one below 50 was a low level of fitness. (34:118)

Modifications and revisions of the original step test have been many and varied. Generally, the research and the resulting test revisions have involved changes in either the height of the bench or the cadence at which the stepping exercise was performed, although consideration was also given to an individual's size.

Gallagher and Brouha (62) devised a step test suitable for high school boys. They used the body surface area to determine what the height of the bench should be. If the body surface area index, which was calculated according to height and weight, was under 1.85, the boy used the eighteen-inch bench; if the index was above the 1.85 level, the regular twenty-inch bench was used. Others also lowered the height of the bench for adolescents to eighteen inches while the speed remained the same. (61; 69)

Elbel and Green (58) tested seventy-two aviation

students on benches of varying heights: twelve, fourteen, sixteen, eighteen, and twenty inches. Each subject was tested for thirty seconds and for one minute on each bench at the rate of twenty-four steps per minute. The pulse rate immediately after the thirty seconds of exercise was 3.7 beats per minute faster for each additional two inches of bench height. After a minute of exercise the increase was 5.6 beats per minute for each two inches of increased height, and thus they concluded that longer exercise on the same height of bench caused a greater increase in the pulse rate. The pulse rate taken from sixty to ninety seconds after the end of exercise was sufficiently long to enable the pulse to return to its normal rate.

Keen and Sloan studied the relationship of body height and leg length to performance on the Harvard Step Test by testing seventy-five male subjects. They discovered that stature, height, leg length, and bi-iliac diameter did not show a correlation with the test results and thus could not justify a lowering of the bench for shorter men.

For women there also have been many revisions and changes in the original test. Brouha and Gallagher (42) also modified the step test for girls by reducing the height of the bench to sixteen inches and by continuing the stepping for only four minutes of time. Ryhming (104) revised the test, lowering the bench to thirteen inches

and slowing the pace to a rate of twenty-two and one-half steps per minute.

In Clarke's modification for college women, she administered the test to Radcliffe College women for four minutes on an eighteen-inch bench. After correlating the scores with Harvard men's scores, it was reported that the decreased duration and the reduced height of the bench still provided a reliable measure of cardiovascular efficiency. (46)

Sloan (112) attempted to determine the best height of the bench for women by using three different heights: twenty inches, eighteen inches, and sixteen inches. The women performed the test once on each bench on different days, and those scores were correlated with the scores made previously by male medical students on a twenty-inch bench. The eighteen-inch bench correlated the highest of the three varying heights. He then used a second group of women subjects and administered the test on eighteen-inch, seventeen-inch, and sixteen-inch benches, using the same procedures as above. The seventeen-inch bench correlated the highest of these three bench heights, and Sloan thus recommended that a bench of seventeen inches could be used for women, with as much reliability as the twenty-inch bench for men.

In a recent preliminary study by Skubic and Hodgkins (110), ninety-six females, aged twelve to

twenty-six, were subjected to both the five-minute and the three-minute step tests at a rate of twenty-four steps per minute on an eighteen-inch bench. After one minute of rest after the end of the exercise, the thirty-second pulse reading was taken. All variables were the same except the length of the exercise duration, and a correlation of .79 was found to exist between these two tests.

Skubic and Hodgkins (110) then studied the effects of the three-minute step test on four groups: trained competitive swimmers, moderately active girls, active girls, and sedentary girls. Telemetering or radio-electrocardiograph (RKG) was utilized in order to record the pulse rates during exercise, although the recovery rate was taken by palpation of the carotid artery. To obtain a cardiovascular efficiency score, the short-form formula (15:240) was slightly changed:

$$\text{Efficiency Index} = \frac{\text{Duration of exercise (sec.)} \times 100}{5.6 \times \text{recovery pulse}}$$

The results of their study indicated that:

1. The three-minute test is sufficiently strenuous enough to be classified as hard work for girls and women.
2. This test discriminates to a high degree among subjects in an excellent state of physical condition, moderate, active, and sedentary.
3. This test is valid and reliable as an instrument for determining cardiovascular efficiency of girls and women.

4. Physical education major students appear to be highly reliable in checking pulse rates of subjects after exercise.
5. Age is not a factor in the step test among females of junior high, senior high, and college age. (110:198)

Pulse rate. Since most of the cardiovascular efficiency test involved the pulse rate as the primary measure, it seemed essential to review pulse rate in terms of its value. Is it a reliable and valid indicator?

Pulse rate is not a perfect measure, by any means, but it has provided information when more extensive machine and instrument methods, such as oxygen intake, cardiac output, and heart rate, were not feasible to undertake.

The rate at which an individual can recover from strenuous exercise has been a commonly used measure of fitness, but there was disagreement concerning its value. Cureton stated that:

Heart rate serves as an indication of condition, since it is relatively low in a well-trained state, it increases less in the athletic person and it returns more promptly to its normal rate than it does in the sedentary individual. (8:34)

Cureton also felt that the quick recovery of the pulse rate to the starting standing normal is one of the most valid tests of fitness if the exercise is hard enough. (8:167) He was of the opinion that:

The recuperation time of the pulse to return

to normal approximately parallels the circulatory-respiratory efficiency to buffer the fatigue products in the blood after exercise and restore normality. (8:162)

Mathews, on the other hand, disagreed with this and said that:

There is little if any correlation between an ability to sustain maximal or exhausting work and the return to normal of the pulse rate during recovery. For mild exercise the return of the heart to normal following work does give some indication of the cardiovascular condition. (16:189)

Mathews (16:188) and Morehouse and Miller (20:104) were in agreement that the time required for the pulse to return to normal depends on the intensity of the exercise and on the physical condition of the individual. Better physical condition will cut down on the time required for the return-to-normal pulse rate. As Morehouse and Tuttle stated:

The rate of deceleration following exercise is directly related to the intensity of the exercise and the elevation of the pulse rate immediately after exercise. The recovery time is prolonged in relation to the intensity of the work and is not related to the resting pulse rate. (20:105)

Cureton reported that Bowen was the first physical educator to study the pulse rate and its relationship to exercise and fitness. (8:65) Bowen concluded that the pulse rate is due to:

1. Speed of exercise

2. Effort of exercise
3. Physiological condition of the subject
4. Age
5. Posture and mental state of subject (8:65)

Brouha and Radford pointed out that age, sex, and fitness influence the cardiovascular rate. (14:178)

There are many other variables contributing to the variations in the pulse rates. Larson (76) indicated that the factors affecting cardiovascular rates were exercise, sex, age, diurnal changes, season and climate, altitude, digestion, changes in body position, air and water movements, loss of sleep, respiration, metabolism, and emotional and nervous condition.

It was generally agreed that the pulse rate increases in proportion to the work load per unit of time in dynamic exercise. (16:185; 10:74; 14:178) The maximum heart rate reached during exercise and the rapidity with which the maximum is attained vary with a number of factors: (1) intensity and duration of exercise, (2) emotional content of exercise, (3) environmental temperature and humidity, and (4) physical condition of the subject. (20:102)

Malhotra and others (80) reported a high linear correlation between the pulse rate and energy expenditure. They gave seven subjects different grades of exercise on a bicycle ergometer with a work load of from fifty to six-hundred kilograms per minute, and caloric expenditure

was calculated by the collection of expired gases and by recording pulse rates. Cureton, however, reported that the pulse rate is not always directly proportional to the severity of the exercise because of the contributing variable of skill and other physiological adjustments.

(8:162)

Sloan (113) subjected four groups of college women to the modified Harvard Step Test on an eighteen-inch bench. His conclusions indicated that the resting pulse rate showed little correlation with either the subject's fitness indices or with height and weight. Keen and Sloan (71), in a study of college men, however, reported that the resting pulse rate was inversely related to the fitness index as calculated by the modified Harvard Step Test.

Schnebel and Elbel (107) subjected forty-five male subjects to five one-minute exercise periods, in which they stepped on and off a sixteen-inch bench at the rate of thirty steps per minute. After checking the pulse rate readings taken five seconds after each exercise bout, they concluded that the recovery time was not related to the amount of pulse rate increase resulting from exercise and that pulse rate was not independent of the effects of previous exercise.

DeVries (10) suggested that a slow, straining exercise, such as an isometric exercise, rarely created

a sufficient enough work load to significantly increase the heart-rate response.

In an exercise that involves a held position . . . as in weight lifting, only a very slight increase in heart rate is observed. At the other end of the continuum are exercises that involve rapid and vigorous alternating contractions, such as running, bicycle riding, etc. in which a large increase in heart rate occurs. (10:74)

As mentioned above, age, sex, climate, and digestion also were contributing factors to pulse rate. Children's pulse rates are normally higher than adult rates. The heart rate is lowered in adulthood but then increases again in old age. (15:164) The average male heart rate is seventy-eight beats per minute (10:70; 20:101), and the women's rates reportedly were from five to ten beats faster under any given set of conditions. (10:71; 20:101; 15:164) Climate must be an important consideration in assessing the pulse rate since high temperatures, high humidity, and high altitude all result in a higher pulse rate. (10:72) After eating, when the digestive processes are in full operation, the heart rate is noticeably faster. Karpovich stated that the "digestion of food invariably accelerates the heart rate for two to three hours." (15:165)

Body posture exerts a great influence upon the heart rate. The pulse is slower in a lying position than in a sitting position, and the standing position is the

highest of the three positions. (20:102; 15:164) A slow pulse rate in the reclining and standing position with a small difference between the two is usually regarded as a sign of excellent physical condition. (15:164)

The heart rate is affected by other factors as well. Excitement increases the heart rate by as much as nineteen beats per minute. "The effects of excitement can be most readily observed at rest but it tends to result in excessive cardiovascular adaptation in exercise as well." (10:72) ". . . Waiting to be given a pulse rate test may greatly affect the pulse rate." (15:166) Smoking, too, has been reported to increase significantly the heart rate. (10:72) The size of the individual may exert an influence on the heart rate, but no consistent relationship has been found. (10:72)

With these external and internal elements affecting a pulse-rate reading, it can be observed that it may be ". . . very difficult and even impossible to obtain a normal resting pulse." (15:165)

The chief complicating factor in studying relationships between the resting and post-exercise pulse rates is the difficulty in obtaining a true resting pulse. It takes so much time and precaution that often the acceptable resting pulse is that which is obtained after an insufficient period of rest from all disturbing influences, at which two consecutive readings happen to check. (15:174)

Despite, however, the various complications and outside

influences involved in taking the pulse rate, Cureton stated that:

The pulse rate tests make the easiest and simplest way to check circulatory-respiratory fitness. Pulse rate does not represent a complete test of circulatory-respiratory fitness but the pulse is the easiest to measure and is the most reliable of the physiological variables which reflect the internal bodily efficiency in response to exercise. (8:162)

III. CARDIOVASCULAR SYSTEM AND ISOMETRIC EXERCISE

The investigations into the area of isometric exercise and its relationship to the cardiovascular system are relatively limited in number. Quite recently, however, there has been much more research delving into this relatively unexplored relationship. Most of the studies have been concerned with the relationship of isometric exercise to heart rate, recovery rate, blood pressure, and energy cost.

Schvartz (109) investigated the relationship between isometric exercise and the heart rate, using ten college students as subjects. The isometric exercise group did four-second contractions with two-second rest periods for a total of forty-five seconds, while the isotonic group exercised for forty-five seconds at one-half of maximum effort. The load had been predetermined to constitute an all-out effort. The mean of the heart-rate increase for the isometric group was 99.1 compared with

the isotonic group's mean of 101.3, whereas the resting pulse rate mean was 71.8. The 43 per cent increase did not represent a significant-enough increase to develop cardiorespiratory fitness. When the effort was increased, however, to two-thirds of the maximum strength, there was almost a two-fold increase which was significant.

Conclusions of this study were that:

1. Isometric exercise performed for 45 seconds at one-half maximum strength load increased the heart rate to the same extent that isotonic exercise did, performed with equal intensities and durations.
2. Increasing the isometric load proportionally increases the heart rate, and that exertion of maximum isometric tension increases the heart rate two-fold. (109:125)

Glad (129) placed sixty-three undergraduate male students into three groups: (1) an isometric exercise group using the "Commander Set" developed by Steinhaus and Giaque, (2) an isotonic group using the Royal Canadian Air Force 5BX Plan, and (3) a control group. Weekly records of behavior variables (sleep, nutrition, general health) were kept for each individual subject, and testing occurred every three weeks. The working pulse rate was recorded by a photoelectric transducer while the subject rode a bicycle ergometer at the rate of 1200 kpm/minute for five minutes. Conclusions of the study indicated that:

1. In healthy young men both isometric and isotonic training can produce significant reductions in working pulse rate while

riding the bicycle ergometer.

2. There is no difference between isometric and isotonic training, as represented in this investigation, related to their effect on the working pulse rate.
3. Changes in the working pulse rates, observed in the exercise groups, were due to training and not to individual differences among men. (129:4)

Bender (123) concurred with these findings by reporting that in a recent pilot study utilizing telemetry, the subjects, when doing isometric exercise, responded with no greater heart rate than when doing isotonic exercise. It was also shown that the recovery rate was the same for both groups.

A study was completed by Milton (132) in which he studied three distance-running programs and a program of isometric exercises in terms of their respective contributions to the development of cardiovascular efficiency. Four hundred and sixty-nine college males, divided into four groups, exercised for seven weeks and were then compared on the basis of the Harvard Step Test. Findings of the study indicated that all four training programs resulted in significant gains in cardiovascular efficiency at the .01 level of confidence, although all three running groups surpassed the isometric exercise group. Milton also concluded that subjects with high initial status can benefit as much from an isometric exercise program as they can from a thirty-minute per

day running program. "For subjects who are low in cardiovascular fitness, all four training programs are equally effective in improving cardiovascular efficiency." (132:4)

Clarke (49) studied the energy cost of isometric exercise by measuring the oxygen consumption and recovery on a closed-circuit metabolic apparatus. The subjects performed five minutes of isometric exercises with fifty, thirty-five, and twenty-pound weights, and Clarke reported that within the three isometric work loads:

The size of the oxygen income, the debt, and the total oxygen requirement all seem to increase linearly in proportion to the size of the weight held by the muscles. (49:5)

He also indicated that there was a significantly smaller oxygen income during work and a larger oxygen debt when static exercise was compared with dynamic exercise at comparable metabolic work loads. This is consistent with the theory that circulation is being occluded by muscle tension, thus requiring the cost of the work to be met by a relatively larger oxygen debt.

The effects of isotonic exercise favor the improvement of muscular endurance and the retention of muscular strength following the cessation of exercise. Isometric contractions restrict the blood circulation to a greater extent than do isotonic contractions. For isometric work the amount of oxygen, the oxygen debt, and the total oxygen requirement increase linearly in proportion to the size of the load. This constriction of circulation with its attendant effects on the oxygen supply to the muscles logically restricts the development

of muscular endurance when training with isometric exercise. (2:47)

The effect of isometric exercise on blood pressure has also been investigated. Tuttle and Horvath (115) reported that static work as measured by maximally squeezing a hand dynamometer for one minute resulted in a rise in both systolic and diastolic arterial pressure with a small oxygen debt, maximum 375 ml. On the other hand, dynamic exercise on a bicycle ergometer produced a systolic pressure increase with a larger oxygen debt.

Royce (102) stated that the blood flow through the muscles is impaired during the maintenance of tension and that much of the energy cost of contraction would need to be paid off in the form of oxygen debt after the muscle has relaxed. It has also been pointed out, however, that the alternating compression and relaxation of muscle pressure against the veins during dynamic exercise tended to promote local blood flow toward the heart and thus increase oxygen transportation, resulting in a comparatively small oxygen debt. (49)

IV. ANTHROPOMETRIC MEASUREMENTS

McCloy and Young have stated that "anthropometric measurements consist of objective measurements of structures and functions of the body." (19:345) Anthropometry has also been referred to as "that branch of anthropology

that is concerned with the taking of measurements on the human body." (14:41) These measurements are the reflection of changes that occur as a result of (1) growth, (2) development as a result of activity, and (3) atrophy as a result of inactivity. (14)

The uses of anthropometry are many and varied. They include the analysis of body build, the comparison between populations, longitudinal studies of a population, and the relationships of body structures to physiological and psychological function. (14) More specifically, anthropometric studies have encompassed the classification of body types; correlation of body type with physical fitness, physical skill performance, and motor fitness; nutritional studies; heredity research; growth studies; and many other areas as well. (1) Anthropometry seeks not only to recognize individual differences but also to determine the individual's potential in relation to his particular structure. (6:127)

Much anthropometric measurement research was located in the literature. For the purpose of this study, however, only that research concerned with the effects of isometric exercise on girth development was considered. In this specific area of anthropometric research, there appeared to be a very limited number of studies.

Day (127), using seventy-two college women as subjects, discovered that six-second isometric contractions

of the abdominal muscles for a six-week period caused a mean reduction of 1.24 inches in the waistline measurement. Isometric exercise did not significantly result in a weight change, however.

A study by Mohr (91) subjected forty women, aged eighteen to forty-five, to four weeks of isometric exercise. Exercising isometrically one minute each day, the subjects reduced their waistline girth as well as reducing the skinfold thickness.

A group of college women exercised using isometric exercises specifically designed for the hips and thighs, while another group used similar but isotonic exercises. After eight weeks significant reductions in the hips and thigh girths were realized by both groups, although neither group was significantly higher than the other. (136)

In contrast to the above findings, Baley (36) reported a slight gain in girth measurements of the upper arm, chest, and thigh, although these gains were not statistically significant. His study involved an eight-week isometric exercise program for underclass college men.

After experimentation with forty-nine male subjects, Basch and Morehouse (98) reported that both isometric exercise and isotonic exercise produce muscle hypertrophy in addition to increasing the strength of the skeletal

muscles.

There is a need for more research investigating the relationship between isometric exercise and girth measurement. The results of the above studies indicated that isometric exercises specifically designed for particular body areas caused a girth reduction, although there was some disagreement, depending on the sex of the subjects.

CHAPTER IV

PROCEDURES

I. PILOT STUDY

Prior to the actual experimentation of this study, a four-week pilot study was undertaken in order to ascertain whether the selected measures and techniques were appropriate and also to identify any administrative difficulties encountered during the testing. As a result of the pilot study recommendations, several changes were made, including the exercises used and the cardiovascular efficiency measure selected. The complete procedures of the pilot study appear in Appendix A for further reference.

II. SELECTION OF SUBJECTS

The subjects selected for the experimental study were freshmen and sophomore women enrolled in three recreational sports classes at The University of North Carolina at Greensboro during the spring semester of 1967. On March 23 the experiment was explained to the classes by the writer, and the volunteers were solicited. When soliciting volunteers, the writer emphasized that anyone participating in other exercise programs or additional sports activities outside of regular class periods would

be ineligible as a participant in the study since this would constitute an uncontrollable variable.

A basic assumption of this study was that the students enrolled in recreational sports classes were representative of a cross section of the student population. Fifty-five girls signed up and were placed into groups by classes as follows: 9:00 A.M. class: Control (fifteen subjects); 10:00 A.M. class: Experimental 1 (nineteen subjects); and 3:00 P.M. class: Experimental 2 (twenty-one subjects). The volunteers signed up for testing times convenient to their schedules on the evenings of April 4 and April 5. The testing intervals allowed for two subjects to be measured and tested in each ten-minute period. The subjects were instructed to wear their gym tunics and to report to Rosenthal Gymnasium at the scheduled time. At the conclusion of the study, ten subjects were dropped for failure to perform the assigned exercises daily, and one subject was dropped for failure to appear for final testing. Thus, the final number of subjects for the various groups was as follows: Control--fourteen; Experimental 1--fourteen; and Experimental 2--sixteen.

III. SELECTION OF MEASURING INSTRUMENT

Tape. A flexible steel tape manufactured by the Lufkin Company was used for all of the anthropometric

measurements in the study. This instrument was selected since it had been proven reliable and very satisfactory in previous research involving girth measurements. (14:44; 136; 134; 127)

The writer's reliability in measuring was checked in a preliminary study with ten graduate students serving as subjects. Using a test-retest procedure, measurements of the upper arm, waist, hips, thigh, and calf were taken on successive nights at approximately the same time. The rank-order correlation statistical method indicated that the writer's measurement technique was reliable. (6; 16)

| <u>Measurement</u> | <u>r</u> |
|--------------------|----------|
| Upper arm | .90 |
| Waist | .84 |
| Hips | .87 |
| Thigh | .97 |
| Calf | .97 |

Since the steel tape was calibrated into inches instead of according to the metric system, a conversion table drawn up by the writer was used in order to facilitate statistical treatment of the data. This conversion table may be found in Appendix D. (One inch = 16.)

Scales. The scales used for the recording of each subject's weight were Chattillon Duplex Pumps scales, Type 1370. The scales were calibrated by placing the

same five-pound barbell weight on them before each measuring session to check the accuracy. Each subject was weighed wearing her tunic but without her shoes, and her weight was recorded to the nearest half-pound.

Electric metronome. The electric metronome used to sound the cadence for the step test was one manufactured by the Franz Manufacturing Company, Inc., in New Haven, Connecticut. An electric metronome was selected to ensure the greatest accuracy in tempo, as recommended by several researchers. (6; 81; 107)

Skubic-Hodgkins Cardiovascular Efficiency Test for College Women. There were numerous tests of cardiovascular efficiency, as reviewed in Chapter III. The Skubic-Hodgkins Test for College Women (110) was the selected measure for the study since it was reported to have high reliability and validity for college women, the subjects of this study. The test was selected, however, only after the first testing session of the pilot study (see Appendix A) when the majority of the subjects were unable to complete the Clarke Step Test (46). The Skubic-Hodgkins Test was a three-minute step test on an eighteen-inch bench at a cadence of twenty-four steps per minute, while the Clarke Test lasted four minutes on the same height of bench at a faster rate of thirty steps per minute.

The three-minute stepping exercise was found to

be strenuous enough to tax the body sufficiently since the task elicited a pulse rate of 150 beats or more per minute (14). The test was correlated with the original five-minute Harvard Step Test, and a .79 correlation was reported.

The test was also found to be highly reliable for untrained and trained subjects alike. A reliability coefficient of .820 was found to exist among untrained subjects by using the test-retest method, whereas the trained subjects' reliability was an almost-identical .825.

The test consisted of stepping on and off an eighteen-inch bench for three minutes at the rate of twenty-four steps per minute in the following manner:

Count one: Step up on one foot.

Count two: Step up on the other foot.

Count three: Step down with the first foot.

Count four: Step down with the other foot.

Uniform instructions were read for each individual subject, and a practice trial was given each subject. A copy of the instructions may be located in Appendix A. At the completion of the three-minute exercise, the subject sat down in an adjacently placed chair to recover for a one-minute period. The tester then recorded the recovery pulse, by palpation of the carotid artery (20), for the thirty-second period from one minute to one and a half minutes.

Physical education major students, graduate and

undergraduate, were trained in the administration of the test. Their technique in the pulse reading of the carotid artery was also checked until the writer deemed it reliable. Skubic and Hodgkins (110) concluded that physical education major students were highly reliable in checking recovery pulse rates in this manner.

With the following formula, a cardiovascular efficiency score was obtained for each subject: (110)

$$\frac{\text{No. of seconds completed} \times 100}{\text{Recovery pulse rate} \times 5.6} = \text{Cardiovascular Efficiency Score}$$

IV. FIRST TESTING SESSION

Upon reporting to Rosenthal Gymnasium at the scheduled time on the evening of either April 4 or April 5, each subject was directed to the graduate dressing room. Only the subject and the writer were present for the measuring session. After removing her shoes, the subject stepped onto the scales, and her weight was recorded to the nearest half-pound. It was necessary to weigh each subject since a change in weight might influence girth measurement. Therefore, if a subject changed in weight more than 3 per cent from the pre-testing to the post-testing, she was automatically dropped from the study. (91)

Moving to the stadiometer platform, the subject stood erect with her feet centered on the tape markings, six inches apart, and she distributed her weight evenly

in preparation for measurement. This position is illustrated in Figure 1 in Appendix C. All measurements were taken and recorded by the writer in order to ensure the highest possible reliability. In order to assure the exact location of each measurement reading, with the exception of the waist, the point of the centimeter scale on the stadiometer was recorded in addition to each measurement. The measurements were taken as follows:

Upper arm girth. The tape was placed around the dominant upper arm at the place of the greatest girth (over the bulge of the biceps and the triceps). Sufficient tension was exerted to contract the extremity without the compression of tissues. (27; 124)

Waist girth. The tape was placed, next to the subject's skin, around the waist at the smallest point and held there through a period of inhalation and exhalation. The mean measurement was recorded. (19; 134)

Hip girth. The tape was placed around the subject at the place of the greatest circumference. Attention was given to making certain that the tape was horizontal and that the measurement was read at the side of the subject. (127)

Thigh girth. The tape was placed around the thigh at the point of the greatest circumference. (27; 6)

Calf girth. The tape was placed around the maximum

circumference of the calf and roughly at right angles to the vertical plane. (6; 124)

Following the measurement session, the subject replaced her shoes and reported to the research laboratory. She was instructed to sit in a chair outside the laboratory door and wait until called. Each subject was tested individually with only the subject and two testers present. The testers, previously trained physical education major students, administered the Skubic-Hodgkins Cardiovascular Efficiency Test for College Women to each subject. Uniform instructions (see Appendix A) were read from a card to each subject, who was then allowed to practice the stepping procedure one or two times to the cadence. The cadence of ninety-six beats per minute or twenty-four steps per minute was signaled by an electric metronome. At the signal "ready-go," the subject began the stepping exercise.

At the completion of the three minutes of exercise, the subject stopped and immediately sat down in a chair that had been placed adjacent to the bench. The electric metronome was turned off immediately to eliminate its distracting influence and so as not to interfere with the pulse count. The tester timed the minute recovery period and then recorded a thirty-second recovery pulse rate by the carotid artery palpation method.

If the subject did not maintain the pace set by the metronome, she was stopped by the tester fifteen

seconds beyond the point when she first lost the pace. This was to allow her to recover the "beat," so to speak. If she could regain the required pace within the fifteen-second period, she was allowed to continue. When stopped, the total exercise time was then noted and recorded on the scorecard; and the one-and-a-half-minute recovery period was timed starting at this point.

If a subject reached the point of fatigue where she literally could not "take another step," she stopped herself and sat down in an adjacently placed chair to begin her recovery period. The tester recorded the total exercise time and began timing the recovery period of one and a half minutes at this point.

The tester employed two stop watches for the test: one timed the duration of the exercise, and the other timed the minute-and-a-half recovery period from the second the subject ceased the exercise. An extra stop watch was available in the event it may have been needed.

As soon as each subject was completed, another subject was immediately called into the laboratory and the same procedure was followed. In this manner, it was possible to measure and test two subjects in each ten-minute period of time.

V. SELECTION OF EXERCISES

The isometric exercises selected for the study were

selected with the intention of determining whether a change occurred in the girth of five body areas: upper arm, waist, hips, thigh, and calf. The exercises therefore were picked to work specifically on these five body parts. The literature in the area of isometric exercise is vast (see Chapter III) and was reviewed carefully. The experimenter looked not only for exercises that would affect the above-mentioned body areas but also for exercises that, when done as a series, would not require more than ten minutes of time to execute. With these points in mind, the following exercises were selected:

Sit-up. (91) Subject is on her back with hands clasped behind her head and legs straight. The head and shoulders are raised from the floor for the designated length of time. This exercise is illustrated in Figure 2 of Appendix C.

Back-lifter. (33) Subject lies on her back with her arms at her sides, palms down. She presses palms down onto the floor, raising the back from the floor, and holds this position for the designated number of seconds. The Back-lifter is illustrated in Figure 3 of Appendix C.

Tummy and Hip Tightener. (127; 133) Subject is on her back on the floor, legs straight. She tightens her abdominal and gluteal muscles simultaneously for the correct number of seconds. Figure 4 in Appendix C

illustrates this exercise.

Towel Puller--Legs. (4) Subject lies on her back and hooks the towel under the foot of one leg, which has been raised to a right angle with the floor. The knee is bent and subject pulls for the appointed length of time and then repeats with the other leg. This exercise is illustrated in Figure 5 of Appendix C.

Towel Puller--Arms. (4; 133) In a standing position with raised arms straight overhead, the subject pulls outward on a towel for the designated amount of time. Figure 6 of Appendix C illustrates the exercise.

Pusher-Puller. (4) Subject keeps arms parallel to the floor and extended in front of her, palms downward. She bends arm to a right angle and grasps wrist with the other hand. Attempting to bring the bent arm toward the body, she resists with the holding arm for the correct number of seconds. This is repeated with the other arm. The Pusher-Puller is illustrated in Figures 7 and 8 in Appendix C.

Cross-Handed Push--Sitting. (22) Sitting in a chair with her feet on the floor, the subject places her hands on the insides of the opposite leg's knee. She attempts to bring the knees together but resists this movement with her hands and arms for the designated period of time. Figures 9 and 10 in Appendix C illustrate

this exercise.

The above exercises, however, were changed somewhat from those originally used in the pilot study (see Appendix A). One of the arm exercises used in the pilot study (see Appendix A, Exercise 4) was dropped because the writer felt that other exercises fulfilled the same purposes. The Cross-Handed Push exercise was added for the thighs since the subjects in the pilot study indicated a special concern about concentrating on this particular body area. The Tummy and Hip Tightener exercise position was changed to a back-lying position since hyperextension of the knees appeared to be accompanying the exercise when the subjects were in standing position, as in the pilot study.

Each of the exercises was performed twice, with the length of the contraction dependent upon the particular experimental group. Experimental Group 1 held each contraction for six seconds with a six-second relaxation period. Experimental Group 2 contracted for twelve seconds with a six-second rest period between contractions. The Control Group did not exercise at all except for the activity received in the recreational-sports class.

The length of the six-second contraction was recommended by Hettinger and Müller and others (93; 96; 116), who stated that a contraction of six seconds was sufficient for optimum results and that a longer contraction

would not yield any better results.

The twelve-second contraction was to determine whether or not the above hypothesis was accurate and to determine if a longer contraction might tax the body sufficiently to improve cardiovascular efficiency more than the six-second contraction.

VI. EXERCISE SESSIONS

During the first class period after the testing sessions, April 6, the subjects participating in the experiment were given an exercise instruction sheet and a reminder card (see Appendix B) since the subjects would be exercising at home or in the dormitory on their own and would be unsupervised.

The subjects were taken outside on the field where the writer explained and demonstrated each of the exercises and clarified any questions. The class then performed the particular exercise. This same procedure was followed for all the exercises except the Cross-Handed Push exercise, which required a straight chair obviously unavailable on the field. The subjects repeated the entire series--except for the above-mentioned exercise--as they were to execute the series of exercises daily, i.e., the correct number of contractions and the correct length of contraction. The writer timed the exercises with a stop watch and explained that it would be essential to use a clock

with a sweep second hand to perform the exercises, the clocks in the dormitory hallways being ideal for this purpose.

The experimenter stressed the importance of faithful participation daily and asked that whenever anyone missed an exercise period, to report this to her during the next class period. The subjects were asked to exercise at approximately the same time each day if at all possible.

The Control Group did not exercise during the experimental period and, as were the other groups, were asked to refrain from additional sports activities during the experiment.

Experimental Group 1 performed each exercise for six-second contractions with six-second rest periods between contractions and between exercises, the entire series consuming slightly longer than three minutes.

Experimental Group 2 executed each exercise with a twelve-second contraction and with the same six-second break between contractions and between exercises. The total length of time for the series of exercises for this group was almost five and one-half minutes.

The exercise period began on April 7 and ended on May 12, a period of five weeks.

VII. FINAL TESTING SESSION

The final testing sessions were held on the evenings

of May 16 and May 17 from 6:30 to 8:00. The subjects signed up, as before, for a testing time that was convenient for them but also which was within twenty minutes of their original testing time. This was done to control as much as possible the variable of food digestion. Identical procedures were used for the final testing period as those used during the first testing session.

VIII. TREATMENT OF THE DATA

The researcher checked the initial cardiovascular efficiency test mean scores by using Fisher's "t" tests of significance (31:380) to determine whether the groups were equated. The 5 per cent level of confidence was accepted for statistical significance. Since the results of these "t" tests showed that there was no significant difference among the three groups, they were assumed to be equated; and it was concluded that the subjects were therefore drawn from a like sample with regard to cardiovascular efficiency. (See Table I.)

The observation was made that there were no subjects of extreme body type (i.e., extremely heavy or extremely thin), and the researcher deemed it unnecessary to determine whether the groups were equated in terms of girth measurements. In addition, the analysis of variance would be based upon the changes that occurred rather than upon the initial test score

TABLE I

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN SCORES
OF INITIAL CARDIOVASCULAR EFFICIENCY TEST

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|-------|
| Control | 14 | 45.37 | .172 |
| Experimental 1 | 14 | 46.13 | |
| Control | 14 | 45.37 | 1.092 |
| Experimental 2 | 16 | 41.00 | |
| Experimental 1 | 14 | 46.13 | 1.338 |
| Experimental 2 | 16 | 41.00 | |

and the final test score.

A test-retest experimental design was utilized in the study, providing the experimenter with initial test and final test scores for comparison. Since the results included not only a cardiovascular efficiency but also five girth measurements for each subject, an analysis of variance (11:237) was computed on the basis of the changes from the initial test score to the final test score.

If a significant change was indicated as a result of the analysis of variance, the following "t" formula (11:238) was used to determine between which groups the significant change occurred:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_w^2}{N_1} + \frac{s_w^2}{N_2}}}$$

The mean of the changes in each group was also computed and "t" tests (11:138-39) were run to determine if the changes within each group were significant, i.e., the changes from the initial test to the final test.

CHAPTER V

ANALYSIS AND INTERPRETATION OF DATA

I. INTRODUCTION

It was the purpose of this study to determine (1) the effects of isometric exercise upon cardiovascular efficiency and (2) the effects of isometric exercise upon selected anthropometric measurements.

The following analysis of data was computed on forty-four of the original fifty-five study participants, all members of three recreational sports classes during the second semester of 1966-67 at The University of North Carolina at Greensboro. Ten of the original subjects who were not included in the final analysis were dropped for failure to complete the required daily exercises, and one subject was dropped since she was unable to appear for final testing.

The volunteer subjects were placed according to classes into three groups--one control group and two experimental groups. Experimental Group 1 performed assigned isometric exercises daily, using a six-second contraction. Experimental Group 2 performed identical exercises daily but used a longer contraction of twelve seconds. The Control Group did no isometric exercises

for the duration of the study. Selected girth measurements were taken, and a cardiovascular efficiency test was administered to all groups at the beginning and at the conclusion of the study.

In order to determine whether the differences among the three groups' final measurements were large enough to indicate significance, the analysis of variance (11:237) was employed. The null hypothesis was formulated that the samples were essentially alike and that no change had occurred. The analysis of variance technique was used on the six different measures included in the study:

(1) cardiovascular efficiency, (2) upper arm measurement, (3) waist measurement, (4) hip measurement, (5) thigh measurement, and (6) calf measurement. In order to reject the null hypothesis, an F score of 3.22 was necessary for significance at the 5 per cent level of confidence.

When a significant change was indicated by the analysis of variance, multiple comparisons were conducted to determine between which group means a significant difference existed. A "t" score of 2.69 was significant at the 5 per cent level of confidence.

To determine whether a significant change occurred between the initial test score and the final test score within each group, "t" tests (11:138-39) were run on the six measures for each of the three groups. A "t" score of 2.16 was necessary for the rejection of the null

hypothesis at the 5 per cent level of confidence.

II. CARDIOVASCULAR EFFICIENCY

Statistical Analysis

When the group means of the cardiovascular efficiency scores were subjected to the analysis of variance, the resulting F score of 5.01 was significant at the 5 per cent level of confidence (see Table II). This indicated that the differences among the three groups were large enough to be significant, and thus comparisons between group means were conducted employing "t" tests.

A mean increase of 5.80 in Experimental Group 1 was computed to be a significant change over the Control Group at the 5 per cent level of confidence. The twelve-second isometric contraction group, Experimental Group 2, also significantly increased over the Control Group but at the 1 per cent level of confidence. There was no significant difference between Experimental Group 1 and Experimental Group 2, however. (See Table III, page 66.)

Additional "t" tests were used to determine the change within each group, using initial test score means and final test score means. (See Table IV, page 67.) The results of these tests showed that there was no significant change in the Control Group, even though there was a slight increase in the cardiovascular efficiency score. The experimenter attributed this score increase

TABLE II

ANALYSIS OF VARIANCE OF CARDIOVASCULAR
EFFICIENCY SCORES

| Source of Variation | Sum of Squares | df | Mean Squares | F |
|------------------------|-------------------|----|-----------------|-------|
| Between groups | 282.79 | 2 | 141.40 | |
| Within groups | 1214.27 | 43 | 28.24 | 5.01* |
| Total | 1497.06 | 45 | | |

*Significant at the .05 level of confidence.

TABLE III
SIGNIFICANCE OF DIFFERENCE BETWEEN FINAL CARDIOVASCULAR
EFFICIENCY TEST MEAN SCORES

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|---------|
| Control | 14 | 1.08 | -2.35* |
| Experimental 1 | 14 | 5.80 | |
| Control | 14 | 1.08 | -2.89** |
| Experimental 2 | 16 | 6.71 | |
| Experimental 1 | 14 | 5.80 | -.47 |
| Experimental 2 | 16 | 6.71 | |

*Significant at the .05 level of confidence.

**Significant at the .01 level of confidence.

TABLE IV

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN DIFFERENCES FOR
INITIAL AND FINAL CARDIOVASCULAR EFFICIENCY TEST SCORES

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | 1.08 | .923 |
| Experimental 1 | 14 | 5.80 | 3.39** |
| Experimental 2 | 16 | 6.71 | 4.70** |

**Significant at the .01 level of confidence.

however, either to greater familiarity with the measuring instrument, the Harvard Step Test modification, or to the twice-weekly recreational sports classes which may have been a contributing factor. When the initial test scores were compared with the final test scores, both Experimental Group 1 and Experimental Group 2 showed significant improvement at the 1 per cent level of confidence.

Discussion

Since both Experimental Group 1 and Experimental Group 2 significantly increased over the Control Group and since there was no difference statistically between Experimental Group 1 and Experimental Group 2, it may be concluded that a daily program of isometric exercise, regardless of whether utilizing a six-second contraction or a twelve-second contraction, was effective in the development of cardiovascular efficiency within a five-week period of time.

The fact that both Experimental Group 1 and Experimental Group 2 significantly increased from the initial test to the final test, while the Control Group did not show a significant increase, supports the above conclusion. In addition, if the twelve-second contraction is not more effective than the six-second contraction, then, in terms of time expenditure, six seconds would be a sufficient length of contraction when attempting to

develop cardiovascular efficiency.

When isometric exercise was used to develop strength, several authorities advocated the six-second contraction and indicated that contracting for any longer is superfluous effort and will not achieve any greater results. (93: 96; 116) Thus, it would appear that for developing cardiovascular efficiency as well as for developing strength, the six-second isometric contraction is effective.

The results of this study also support those of Milton, who also found a significant increase in cardiovascular efficiency, as measured by the Harvard Step Test, after a program of isometric exercise. (132)

Bender, however, stated that three types of conditioning are necessary in physical education and athletics: (1) cardiovascular efficiency, (2) muscular strength, and (3) muscular endurance; and that of these three, ". . . isometrics can develop only strength." (39:21) The above results appear to contradict this statement by showing that isometric exercise can significantly improve cardiovascular efficiency.

III. UPPER ARM GIRTH

Statistical Analysis

The analysis of variance for the means of the three groups' upper arm girth measurements was found to be significant at the 5 per cent level of confidence.

indicating that significant change had occurred between some of the mean scores or between all of the mean scores. (See Table V, page 71.)

The "t" tests for uncorrelated means were computed, and a significant difference was found to exist between the Control Group and Experimental Group 1. There was no significant difference, however, between the Control Group and Experimental Group 2 or between Experimental Group 1 and Experimental Group 2. (See Table VI, page 72.)

The "t" values were computed for the means of the initial measurement and the final measurement for all groups. Both Experimental Group 1 and Experimental Group 2 differed significantly at the 1 per cent level of confidence, whereas the Control Group did not significantly change. (See Table VII, page 73.)

Discussion

Since there was a significant difference between Experimental Group 1 and the Control group, it could be assumed that a five-week period of daily isometric exercise, using a six-second contraction, was effective in significantly reducing upper arm girth. Although there was no statistically significant difference between Experimental Group 1 and Experimental Group 2, a noticeable difference existed between the two groups' actual mean scores. Experimental Group 1 achieved a mean decrease of 4.29,

TABLE V

ANALYSIS OF VARIANCE OF UPPER ARM MEASUREMENTS
OF THREE GROUPS

| Source of Variation | Sum of Squares | df | Mean Squares | F |
|---------------------|----------------|----|--------------|-------|
| Between groups | 62.73 | 2 | 31.37 | |
| Within groups | 406.04 | 43 | 9.44 | 3.32* |
| Total | 468.77 | 45 | | |

*Significant at the .05 level of confidence.

TABLE VI
SIGNIFICANCE OF DIFFERENCE BETWEEN FINAL UPPER ARM
MEASUREMENT MEAN SCORE

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | 1.43 | -2.47* |
| Experimental 1 | 14 | 4.29 | |
| Control | 14 | 1.43 | - .63 |
| Experimental 2 | 16 | 2.13 | |
| Experimental 1 | 14 | 4.29 | 1.93 |
| Experimental 2 | 16 | 2.13 | |

*Significant at the .05 level of confidence.

TABLE VII

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN DIFFERENCES
FOR INITIAL AND FINAL UPPER ARM MEASUREMENTS

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | 1.43 | 1.44 |
| Experimental 1 | 14 | 4.29 | 4.98** |
| Experimental 2 | 16 | 2.13 | 3.43** |

**Significant at the .01 level of confidence.

or slightly more than one-quarter inch, whereas the actual decrease of Experimental Group 2 was only 2.13.

Because the Control Group did not change significantly and because both Experimental Group 1 and Experimental Group 2 did change significantly at the 1 per cent level, these results support the following statement: five weeks of daily isometric exercises, either employing a six-second contraction or a twelve-second contraction, were effective in reducing upper arm girth for the subjects in this study.

IV. WAIST GIRTH

Statistical Analysis

An F score of 6.91, significant at the 1 per cent level of confidence, showed that there was a significant variance among the three groups or within the three groups. (See Table VIII, page 75.)

The "t" values were computed between each of the groups' mean measurements. These results indicated that there was a difference, significant at the 1 per cent level of confidence, between the Control Group and Experimental Group 1. No significant difference existed between the Control Group and Experimental Group 2 or between Experimental Group 1 and Experimental Group 2. (See Table IX, page 76.)

The findings of the "t" tests between the initial

TABLE VIII
ANALYSIS OF VARIANCE OF WAIST MEASUREMENTS
OF THREE GROUPS

| Source of Variation | Sum of Squares | df | Mean Square | F |
|---------------------|----------------|----|-------------|--------|
| Between groups | 284.69 | 2 | 142.35 | |
| Within groups | 885.86 | 43 | 20.60 | 6.91** |
| Total | 1170.55 | 45 | | |

**Significant at the .01 level of confidence.

TABLE IX

SIGNIFICANCE OF DIFFERENCE BETWEEN FINAL
WAIST MEASUREMENT MEAN SCORES

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|---------|
| Control | 14 | .29 | -3.34** |
| Experimental 1 | 14 | 6.00 | |
| Control | 14 | .29 | -1.48 |
| Experimental 2 | 16 | 3.75 | |
| Experimental 1 | 14 | 6.00 | 1.36 |
| Experimental 2 | 16 | 3.75 | |

** Significant at the .01 level of confidence.

mean measurement and the final mean measurement indicated that both Experimental Group 1 and Experimental Group 2 realized changes, significant at the 1 per cent level of confidence. (See Table X, page 78.)

Discussion

Experimental Group 1 differed significantly from the Control Group, and it would therefore seem logical to assume that a five-week program of daily isometric exercises, using a six-second contraction, was the most effective method in this study for significantly reducing waist girth.

Even though Experimental Group 1 and Experimental Group 2 did not statistically differ at a significant level, a substantial difference existed between them. Experimental Group 1 had a mean decrease of 6.00, or three-eighths of an inch, while Experimental Group 2's mean decrease was only 3.75. Thus, regardless of the lack of a statistically significant difference between these two groups, the six-second contraction was slightly more effective.

Since the Control Group did not change significantly and since both Experimental Group 1 and Experimental Group 2 changed significantly at the 1 per cent level, these "t" test results further support the assumption that five weeks of daily isometric exercise, either with

TABLE X

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN DIFFERENCES
FOR INITIAL AND FINAL WAIST MEASUREMENTS

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | .29 | .194 |
| Experimental 1 | 14 | 6.00 | 4.92** |
| Experimental 2 | 16 | 3.75 | 3.91** |

**Significant at the .01 level of confidence.

contractions of six seconds or twelve seconds, were effective in reducing waist girth.

These findings were in agreement with Day (127) and Mohr (91), who also found that isometric exercise was an effective means of decreasing waist girth.

V. HIP GIRTH

Statistical Analysis

The analysis of variance of the three groups' mean score of the hip measurement indicated that a significant variance between the groups existed. (See Table XI, page 80.)

The "t" test results showed a difference between the Control Group and Experimental Group 1 and between the Control Group and Experimental Group 2, both differences significant at the 1 per cent level of confidence. (See Table XII, page 81.)

Significant differences also appeared when "t" tests were run on each of the three groups' initial mean score and final mean score. Changes, significant at the 1 per cent level of confidence, were found to exist in Experimental Group 1 and in Experimental Group 2. No significant changes were found in the Control Group. (See Table XIII, page 82.)

Discussion

Since both Experimental Group 1 and Experimental

TABLE XI

ANALYSIS OF VARIANCE OF HIP MEASUREMENTS OF THREE GROUPS

| Source of Variation | Sum of Squares | df | Mean Square | F |
|---------------------|----------------|----|-------------|--------|
| Between groups | 215.07 | 2 | 107.54 | |
| Within groups | 798.57 | 43 | 18.57 | 5.79** |
| Total | 1013.64 | 45 | | |

** Significant at the .01 level of confidence.

TABLE XII
SIGNIFICANCE OF DIFFERENCE BETWEEN FINAL HIP
MEASUREMENT MEAN SCORES

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|---------|
| Control | 14 | .14 | -2.80** |
| Experimental 1 | 14 | 4.71 | |
| Control | 14 | .14 | -2.78** |
| Experimental 2 | 16 | 4.50 | |
| Experimental 1 | 14 | 4.71 | .13 |
| Experimental 2 | 16 | 4.50 | |

**Significant at the .01 level of confidence.

TABLE XIII

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN DIFFERENCES
FOR INITIAL AND FINAL HIP MEASUREMENTS

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | -.14 | -.098 |
| Experimental 1 | 14 | 4.71 | 5.03** |
| Experimental 2 | 16 | 4.50 | 4.25** |

**Significant at the .01 level of confidence.

VI. DISCUSSION

After the analysis of variance, which yielded a significant F score, "t" tests were computed among the three groups. (See Table XIV, page 84.)

The results of the "t" tests indicated that a difference, significant at the 1 per cent level, existed between the Control Group and Experimental Group 1. A

Group 2 showed significant differences over the Control Group, it can be assumed that both of the test variables were not statistically different. The six-second isometric contraction thus proved as effective in reducing hip girth as the longer twelve-second contraction. The five-week daily program of isometric exercise, either with a six-second contraction or with a twelve-second contraction, was effective in reducing hip girth for this study's subjects.

The statistically significant changes which occurred within Experimental Group 1 and within Experimental Group 2 also substantiate the above conclusion that both the six-second contraction and the twelve-second contraction were effective in reducing hip girth.

Vandine (136) also studied the effects of isometric exercise on hip girth, and these findings support her conclusion that a decrease in hip girth resulted from a regular program of isometric exercise.

VI. THIGH GIRTH

After the analysis of variance, which found a significant F score, "t" tests were computed among the three groups. (See Table XIV, page 84.)

The results of the "t" tests indicated that a difference, significant at the 5 per cent level, existed between the Control Group and Experimental Group 1. A

TABLE XIV
ANALYSIS OF VARIANCE OF THIGH MEASUREMENTS

| Source of Variation | Sum of Squares | df | Mean Square | F |
|---------------------|----------------|----|-------------|-------|
| Between groups | 166.74 | 2 | 83.37 | |
| Within groups | 887.17 | 43 | 20.63 | 4.04* |
| Total | 1053.91 | 45 | | |

*Significant at the .05 level of confidence.

difference significant at the 1 per cent level of confidence was found between the Control Group and Experimental Group 2. There was no significant difference between Experimental Group 1 and Experimental Group 2. (See Table XV, page 86.)

The "t" tests run within the groups between the initial mean measurement and the final mean measurement showed a significant change at the 1 per cent level of confidence in Experimental Group 1 and Experimental Group 2. There was no significant change in the Control Group, however. (See Table XVI, page 87.)

Discussion

Since both Experimental Group 1 and Experimental Group 2 realized significant changes and there was no statistical differences between them, it could be assumed that there was no difference in the effectiveness of the six-second contraction and in the twelve-second contraction. Both types of contractions, when utilized in a regular five-week isometric exercise program, were effective means of significantly reducing thigh girth within the limitations of this study.

The thigh measurement was the only measure in the study in which Experimental Group 2, the twelve-second contraction group, changed more than Experimental Group 1, the six-second contraction group.

TABLE XV
SIGNIFICANCE OF DIFFERENCE BETWEEN FINAL
THIGH MEASUREMENT MEAN SCORES

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|---------|
| Control | 14 | .14 | -2.18* |
| Experimental 1 | 14 | 3.86 | |
| Control | 14 | .14 | -2.71** |
| Experimental 2 | 16 | 4.63 | |
| Experimental 1 | 14 | 3.86 | - .46 |
| Experimental 2 | 16 | 4.63 | |

*Significant at the .05 level of confidence.

**Significant at the .01 level of confidence.

TABLE XVI

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN DIFFERENCES
FOR INITIAL AND FINAL THIGH MEASUREMENTS

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | .143 | .11 |
| Experimental 1 | 14 | 3.86 | 3.57** |
| Experimental 2 | 16 | 4.63 | 3.85** |

**Significant at the .01 level of confidence.

Discussion

Since both Experimental Group 1 and Experimental Group 2 were significantly different from the Control Group and yet not significantly different from each other, it may be assumed that isometric exercise, either with a six-second contraction or with a one-second

These results also concurred with Vandine's findings.
(136)

VII. CALF GIRTH

Statistical Analysis

The significant F score indicated that a significant variance existed between or within the mean scores of the three groups. (See Table XVII, page 89.)

The "t" tests showed that changes, significant at the 5 per cent level, occurred between the Control Group and Experimental Group 1 and between the Control Group and Experimental Group 2. There was no significant difference between Experimental Group 1 and Experimental Group 2. (See Table XVIII, page 90.)

It was found that Experimental Group 1 and Experimental Group 2 both significantly changed from the initial mean measurement to the final mean measurement. These changes were significant at the 1 per cent level of confidence. The Control Group did not differ to a significant level. (See Table XIX, page 91.)

Discussion

Since both Experimental Group 1 and Experimental Group 2 were significantly different from the Control Group and yet not significantly different from one another, it may be assumed that isometric exercise, either with a six-second contraction or with a twelve-second

TABLE XVII
ANALYSIS OF VARIANCE OF CALF MEASUREMENTS

| Source of Variation | Sum of Squares | df | Mean Square | F |
|---------------------|----------------|----|-------------|-------|
| Between groups | 37.20 | 2 | 18.60 | |
| Within groups | 209.23 | 43 | 4.87 | 3.82* |
| Total | 246.43 | 45 | | |

* Significant at the .05 level of confidence.

TABLE XVIII

SIGNIFICANCE OF DIFFERENCE BETWEEN FINAL
CALF MEASUREMENT MEAN SCORES

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | .79 | -2.55* |
| Experimental 1 | 14 | 2.93 | |
| Control | 14 | .79 | -2.19* |
| Experimental 2 | 16 | 2.56 | |
| Experimental 1 | 14 | 2.93 | .46 |
| Experimental 2 | 16 | 2.56 | |

*Significant at the .05 level of confidence.

TABLE XIX

SIGNIFICANCE OF DIFFERENCE BETWEEN MEAN DIFFERENCES
FOR INITIAL AND FINAL CALF MEASUREMENTS

| Group | N | \bar{X} | "t" |
|----------------|----|-----------|--------|
| Control | 14 | .79 | .13 |
| Experimental 1 | 14 | 2.93 | 4.37** |
| Experimental 2 | 16 | 2.56 | 4.92** |

*Significant at the .01 level of confidence.

contraction, was an effective means of decreasing calf girth within the limitations of this study.

The findings of the within-group comparisons support the above conclusion since both Experimental Group 1 and Experimental Group 2 significantly changed during the five weeks of exercise.

CHAPTER VI

SUMMARY AND CONCLUSIONS

I. SUMMARY

The purpose of this study was to determine the effects of isometric exercise upon (1) cardiovascular efficiency and (2) the following anthropometric measurements: upper arm girth, waist girth, hip girth, thigh girth, and calf girth.

The subjects for the five-week experimental study were forty-four freshmen and sophomore women enrolled in three recreational sports classes at The University of North Carolina at Greensboro during the spring semester of 1967. The subjects were divided according to their classes into three groups--one control group and two experimental groups. Experimental Group 1 performed a prescribed isometric exercise program, using six-second contractions each day for the five weeks. Experimental Group 2 exercised identically except that this group employed a longer contraction of twelve seconds for each exercise. The Control Group did not participate in any isometric exercise for the five-week period of the study.

In order to determine the effectiveness of isometric exercise upon cardiovascular efficiency and upon girth

measurement, the Skubic-Hodgkins revision of the Harvard Step Test was administered to each subject, and the five girth measurements were taken at the beginning and at the conclusion of the experiment.

The data were statistically treated (1) to determine any differences between the final mean score among the three groups and (2) to determine the differences within the three groups from the initial mean score to the final mean score. The following results were obtained:

1. From the administration of the final cardiovascular efficiency test, statistically significant differences were found between the Control Group and Experimental Group 1 and between the Control Group and Experimental Group 2.
2. From the final upper arm and waist measurements, statistically significant differences were found between the Control Group and Experimental Group 1.
3. From the final measurements of the hips, thigh, and calf girth, statistically significant differences were found between the Control Group and Experimental Group 1 and between the Control Group and Experimental Group 2.
4. From the initial test to the final test in Experimental Group 1 and in Experimental Group 2, a statistically significant change in cardiovascular efficiency was found. No statistically significant

change was found in the Control Group.

5. From the initial measurement to the final measurement in Experimental Group 1 and in Experimental Group 2, a statistically significant decrease in girth was found in all of the five body areas--upper arm, waist, hips, thigh, and calf.

II. CONCLUSIONS

The above findings resulted in the formulation of the following conclusions:

1. In comparison with the Control Group, the daily five-week program of seven selected isometric exercises, using either a six-second contraction or a twelve-second contraction, was effective in increasing cardiovascular efficiency.
2. In comparison with the Control Group, the daily five-week program of seven selected isometric exercises, using a six-second contraction, was effective in reducing girth in the upper arm, waist, hips, thigh, and calf regions of the body.
3. In comparison with the Control Group, the daily five-week program of seven selected isometric exercises, using a twelve-second contraction, was effective in reducing girth in the hips, thigh, and calf regions of the body.
4. The daily five-week program of seven selected

isometric exercises, using either a six-second contraction or a twelve-second contraction, was effective in reducing girth in the upper arm, waist, hips, thigh, and calf regions of the body.

5. The daily five-week program of seven selected isometric exercises, using either the six-second contraction or the twelve-second contraction, was effective in improving cardiovascular efficiency.
6. Although there was no statistically significant difference between Experimental Group 1 and Experimental Group 2, the six-second contraction resulted in a greater reduction of girth than the twelve-second contraction in all girth measurements except that of the thigh girth. Thus, the six-second contraction was as effective or more effective than the twelve-second contraction and would be recommended for the sake of exercise-time expenditure.

III. RECOMMENDATIONS FOR FURTHER STUDY

Further study could include the following areas of investigation:

1. The experiment could be conducted for a period of time longer than five weeks to determine if like findings would result.

2. The girth measurements and cardiovascular efficiency test could be administered in the middle of the experimental period to attempt to determine when the changes, if any, occurred.
3. The study could involve more subjects and could be conducted with male subjects as well as female subjects.
4. Consideration could be given to the menstrual period of the subjects and the effect it may have on certain anthropometric measurements.

BIBLIOGRAPHY

A. HOOKER

1. American Association of Health, Physical Education, and Recreation Research Council. Research Methods in Health, Physical Education, and Recreation. Second edition. Washington, D.C.: American Association of Health, Physical Education, and Recreation, 1959. 536 pp.
2. American Medical Association and the American Association of Health, Physical Education, and Recreation. Exercise and Fitness. Chicago: The Athletic Institute, 1959. 121 pp.
3. Harrow, Harold, and Rosemary Hodes. A Practical Approach to Measurement in Physical Education. Philadelphia: Lea and Febiger, 1964. 360 pp.
4. Isender, Jay A., and _____ Physical Fitness: Tests and Experiments. _____: The Ronald Press Company, 1964. 198 pp.
5. Howard, John P., Frederick W. Cozens, and F. Patricia Hagman. Tests and Measurements in Physical Education. Third edition. Philadelphia: W. B. Saunders Company, 1969. 627 pp.
6. Clarke, B. Harrison. Applications of Measurement to Health and Physical Education. Third edition. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1959. 528 pp.
7. Cureton, Thomas Kirk. Physical Fitness and Dynamic Health. New York: The Ronald Press, 1963. 190 pp.
8. _____. Physical Fitness: Appraisal and Guidance. St. Louis: The C. V. Mosby Company, 1947. 306 pp.
9. _____. et al. Experiments in Young Men. Washington, D.C.: Society for Research in Child Development, National Research Council, 1945. 286 pp.
10. DeVries, Herbert A. Physiology of Exercise for Physical Education and Athletics. Dubuque, Iowa: William C. Brown Company, Publishers, 1966. 402 pp.
11. Ferguson, George A. Statistical Analysis in Psychology

BIBLIOGRAPHY

A. BOOKS

1. American Association of Health, Physical Education, and Recreation Research Council. Research Methods in Health, Physical Education, and Recreation. Second edition. Washington, D.C.: American Association of Health, Physical Education, and Recreation, 1959. 536 pp.
2. American Medical Association and the American Association of Health, Physical Education, and Recreation. Exercise and Fitness. Chicago: The Athletic Institute, 1959. 121 pp.
3. Barrow, Harold, and Rosemary McGee. A Practical Approach to Measurement in Physical Education. Philadelphia: Lea and Febiger, 1964. 560 pp.
4. Bender, Jay A., and Edward J. Shea. Physical Fitness: Tests and Exercises. New York: The Ronald Press Company, 1964. 158 pp.
5. Bovard, John F., Frederick W. Cozens, and F. Patricia Hagman. Tests and Measurements in Physical Education. Third edition. Philadelphia: W. B. Saunders Company, 1949. 427 pp.
6. Clarke, H. Harrison. Application of Measurement to Health and Physical Education. Third edition. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1959. 528 pp.
7. Cureton, Thomas Kirk. Physical Fitness and Dynamic Health. New York: The Dial Press, 1965. 190 pp.
8. ———. Physical Fitness Appraisal and Guidance. St. Louis: The C. V. Mosby Company, 1947. 506 pp.
9. ———, et al. Endurance in Young Men. Washington, D.C.: Society for Research in Child Development, National Research Council, 1945. 286 pp.
10. DeVries, Herbert A. Physiology of Exercise for Physical Education and Athletics. Dubuque, Iowa: William C. Brown Company, Publishers, 1966. 422 pp.
11. Ferguson, George A. Statistical Analysis in Psychology

- and Education. New York: McGraw-Hill Book Company, Inc., 1959. 347 pp.
12. Hettinger, Theodor. Physiology of Strength. Springfield, Illinois: Charles C. Thomas, Publishers, 1961. 84 pp.
 13. Hoffman, Robert. Exercise Without Movement. York, Pennsylvania: The Hoffman Foundation, 1961. 18 pp.
 14. Johnson, Warren R. (ed.). Science and Medicine of Exercise and Sports. New York: Harper and Brothers, 1960. 740 pp.
 15. Karpovich, Peter V. Physiology of Muscular Activity. Sixth edition. Philadelphia: W. B. Saunders Company, 1965. 305 pp.
 16. Mathews, Donald K. Measurement in Physical Education. Philadelphia: W. B. Saunders Company, 1958. 359 pp.
 17. McCloy, Charles H. Appraising Physical Status: Methods and Norms. Iowa City: University of Iowa, 1938. 224 pp.
 18. ———. Appraising Physical Status: Selection of Measurement. Iowa City: University of Iowa, 1938. 157 pp.
 19. ———, and Norma D. Young. Tests and Measurement in Health and Physical Education. Third edition. New York: Appleton-Century-Crofts, Inc., 1954. 497 pp.
 20. Morehouse, Laurence E., and Augustus T. Miller. Physiology of Exercise. Fourth edition. St. Louis: The C. V. Mosby Company, 1963. 323 pp.
 21. ———, and Philip J. Rasch. Scientific Bases of Athletic Training. Philadelphia: W. B. Saunders Company, 1958. 258 pp.
 22. Obeck, Victor. How to Exercise Without Moving a Muscle. New York: Pocket Books, Inc., 1964. 57 pp.
 23. President's Council on Physical Fitness. Adult Physical Fitness. Washington, D.C.: Government Printing Office, 1963. 64 pp.

24. Rathbone, Josephine L. Corrective Physical Education. Fifth edition. Philadelphia: W. B. Saunders Company, 1959. 318 pp.
25. Schneider, E. C. Physiology of Muscular Activity. Philadelphia: W. B. Saunders Company, 1939. 428 pp.
26. ———, and Peter V. Karpovich. Physiology of Muscular Activity. Fourth edition. Philadelphia: W. B. Saunders Company, 1953. 340 pp.
27. Scott, M. Gladys, and Esther French. Measurement and Evaluation in Physical Education. Dubuque, Iowa: William C. Brown Company, Publishers, 1959. 493 pp.
28. Spackman, Robert R. Two-Man Isometric Exercise Program for the Whole Body. Dubuque, Iowa: William C. Brown Company, Publishers, 1964. 64 pp.
29. Steinhaus, Arthur H. Toward an Understanding of Health and Physical Education. Dubuque, Iowa: William C. Brown Company, Publishers, 1963. 366 pp.
30. ———, et al. How to Keep Fit and Like It. Chicago: Consolidated Book Publishers, Inc., 1943. 64 pp.
31. Van Dalen, Deobald B. Understanding Educational Research. New York: McGraw-Hill Book Company, Inc., 1966. 525 pp.
32. Wallis, Earl L., and Gene A. Logan. Figure Improvement and Body Conditioning Through Exercise. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964. 111 pp.
33. ———, and ———. Isometric Exercise for Figure Improvement and Body Conditioning. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964. 26 pp.
34. Willgoose, Carl E. Evaluation in Health Education and Physical Education. New York: McGraw-Hill Book Company, Inc., 1961. 478 pp.
35. Woods, Harvey. The AMF Method of Isometric Exercise. Chicago: W. J. Voit Rubber Company, 1964. 24 pp.

B. PERIODICALS

36. Baley, James A. "Attitudes of University Freshmen toward Isometric Exercise," Research Quarterly, 38:143, March, 1967.
37. Ball, Jerry R., et al. "Effects of Isometric Training on Vertical Jumping," Research Quarterly, 35:231-35, October, 1964.
38. Barach, J. H. "The Energy Index," Journal of the American Medical Association, 62:525-30, February 14, 1914.
39. Bender, Jay A., et al. "Isometrics: A Critique of Fadism vs. Facts," Journal of Health, Physical Education, and Recreation, 34:21-22, May, 1963.
40. Bookwalter, Karl W. "A Study of the Brouha Step Test," The Physical Educator, 5:8, May, 1948.
41. Brouha, Lucien. "The Step Test: A Simple Method for Measuring Physical Fitness for Muscular Work in Young Men," Research Quarterly, 14:31-36, March, 1943.
42. ———, and J. R. Gallagher. "A Functional Fitness Test for High School Girls," Journal of Health, Physical Education, and Recreation, 14:517, 550, December, 1943.
43. ———, A. Graybiel, and C. W. Heath. "The Step Test: A Simple Method of Measuring Physical Fitness for Hard Muscular Work in Adult Men," Revue Canadienne de Biologie, 2:86-92, October, 1943.
44. Carlson, H. C. "Fatigue Curve Test," Research Quarterly, 16:169-74, October, 1945.
45. Chui, E. F. "Effects of Isometric and Dynamic Weight Training Exercise upon Strength and Speed of Movement," Research Quarterly, 35:246-57, October, 1964.
46. Clarke, Harriet L. "A Functional Fitness Test for College Women," Journal of Health, Physical Education, and Recreation, 14:358-59, September, 1943.
47. Clarke, H. Harrison. "Comparison of Upper Arm

Measurements by Use of Roentgenogram and Anthropometric Techniques," Research Quarterly, 27:279-85, 1956.

48. _____. "Relationship of Strength and Anthropometry to Various Arm Strength Criteria," Research Quarterly, 25:134-43, May, 1954.
49. Clarke, David H. "Energy Cost of Isometric Exercise," Research Quarterly, 31:3-6, March, 1960.
50. Cogswell, R. C., et al. "Effects of Training on Pulse Rate and Blood Pressure in Humans Using Step Test (Harvard), Treadmill, and Electrodynamic Brake Bicycle Ergometer," American Journal of Physiology, 146:422-30, June, 1946.
51. Cook, Ellsworth, and R. J. Wherry. "A Statistical Evaluation of Physical Fitness Tests," Research Quarterly, 21:110, May, 1950.
52. Crampton, C. W. "A Test of Condition," Medical News, 87:529-34, September, 1905.
53. Cureton, Thomas Kirk. "Comparison of Various Factor Analyses of Cardiovascular Respiratory Test Variables," Research Quarterly, 37:317-25, October, 1966.
54. _____. "What Is Physical Fitness?" Journal of Health, Physical Education, and Recreation, 16:162-64, March, 1945.
55. Darcus, H. D., and Nancy Salter. "The Effect of Repeated Muscular Exertion on Muscular Strength," Journal of Physiology, 79:325-36, August, 1955.
56. DeLorme, Thomas L. "Restoration of Muscular Power by Heavy Resistance Exercise," Journal of Bone and Joint Surgery, 27:645-67, October, 1945.
57. Dennison, J. D., et al. "Effect of Isometric and Isotonic Exercise Programs upon Muscular Endurance," Research Quarterly, 32:348-52, October, 1961.
58. Elbel, E. R., and E. L. Green. "Pulse Reaction to Performing Step-up Exercises on Benches of Different Heights," American Journal of Physiology, 145:521-23, February, 1946.

59. _____, and R. M. Holmer. "Relationship Between Pre-Exercise Pulse Rate and Recovery Following Exercise," Research Quarterly, 20:367-77, December, 1949.
60. _____, et al. "Comparison of Certain Tests of Physical Fitness and Certain Bodily Measurements," Journal of Applied Physiology, 12:37-41, March, 1958.
61. Gallagher, J. R. "Static and Dynamic Physical Fitness in Adolescents," Journal of Pediatrics, 24:81-87, March, 1944.
62. _____, and Lucien Brouha. "V. A Simple Method of Evaluating Fitness in Boys: The Step Test," Yale Journal of Biology and Medicine, 15:769-79, 1943.
63. Hamilton, Andrew. "Scientific Secrets of Fitness," Science Digest, 58:60-65. July, 1965.
64. Higdon, Hal. "Let's Tell the Truth about Isometrics," Today's Health, 43:58-59, June, 1965.
65. Hettinger, Theodor, et al. "Assessment of Physical Work Capacity," Journal of Applied Physiology, 16:153-55, March, 1961.
66. Hodgkins, Jean, and Vera Skubic. "Cardiovascular Efficiency Test Scores for College Women in the United States," Research Quarterly, 34:454-61, December, 1963.
67. Howell, M. L., Ray Kimoto, and W. R. Morford. "Effects of Isometric and Isotonic Exercise Programs upon Muscular Endurance," Research Quarterly, 33:536-40, December, 1962.
68. Gemmill, C. W., et al. "The Effects of Training on Recovery Period Following Severe Muscular Exertion," American Journal of Physiology, 96:265-77, 1931.
69. Johnson, T. J., Lucien Brouha, and J. R. Gallagher. "VI. The Use of the Step Test in the Evaluation of Fitness of Adolescents," Yale Journal of Biology and Medicine, 15:781-85, 1943.
70. Joint Committee of American Medical Association and the American Association of Health, Physical Education, and Recreation. "Exercise and Fitness," Journal of Health, Physical Education, and

Recreation, 35:42-44, May, 1964.

71. Keen, E. N., and A. W. Sloan. "Observations on the Harvard Step Test," Journal of Applied Physiology, 31:41, September, 1958.
72. Keeney, Clifford. "Work Capacity," Journal of Health, Physical Education, and Recreation, 31:29-32, September, 1960.
73. Knehr, C., et al. "Training and Its Effects on Man at Rest and at Work," American Journal of Physiology, 136:148-56, March, 1942.
74. Kroll, Walter. "Isometric Training Effects upon Central Facilitation," Research Quarterly, 36:427-32, December, 1965.
75. Larson, Leonard A. "Cardio-Respiratory Function in Relation to Physical Fitness," Research Quarterly (Supplement), 12:456-59, May, 1941.
76. ———. "A Study of Validity of Some Cardio-vascular Tests," Journal of Experimental Education, 7:157-60, March, 1939.
77. Lawther, J. D. "The Penn State University Studies on Strength Development, Maintenance, and Related Aspects," C.P.E.A. Proceedings, 61:142-49, 1958.
78. LeBlanc, J. A. "Use of Heart Rate as an Index of Work Output," Journal of Applied Physiology, 10:275-80, March, 1957.
79. Liberson, W. T., and M. Maxim Asa. "Further Studies of Brief Isometric Exercise," Archives of Physical Medicine and Rehabilitation, 40:330-35, 1959.
80. Malhotra, M.S., et al. "Pulse Count as a Measure of Energy Expenditure," Journal of Applied Physiology, 18:994-96, September, 1963.
81. Mathews, Donald K., and Robert Kruse. "Effects of Isometric and Isotonic Exercise on Elbow Muscle Groups," Research Quarterly, 27:26-37, March, 1957.
82. Mayberry, Robert P. "Isometric Exercise and Cross Transfer of Training as It Relates to Strength," C.P.E.A. Proceedings, 62:155-58, December, 1958.

83. Mayer, Jean. "Exercise Can Keep Us Fit," Journal of Health, Physical Education, and Recreation, 27:12-13, September, 1956.
84. McCloy, Charles H. "Anthropometry in the Service of the Individual," Journal of Health, Physical Education, and Recreation, 5:417-19, September, 1934.
85. _____. "Endurance," The Physical Educator, 5:18, March, 1948.
86. _____. "How About Some Muscle?" Journal of Health, Physical Education, and Recreation, 27:14-15, 38, September, 1956.
87. _____. "What Is Physical Fitness?" Journal of Health, Physical Education, and Recreation, 27:14-15, 38, September, 1956.
88. McCraw, Lynn W., and S. Burnham. "Resistive Exercise in the Development of Muscular Strength and Endurance," Research Quarterly, 37:79-88, March, 1966.
89. McCurdy, James H., and Leonard A. Larson. "Measure of Organic Efficiency for Prediction of Physical Condition," Research Quarterly, 6:9-14, May, 1935.
90. Mitchem, John. "Isometric Exercise--An Evaluation," The Physical Educator, 20:3-4, October, 1963.
91. Mohr, Dorothy. "Changes in Waistline and Abdominal Girth and Subcutaneous Fat Following Isometric Exercise," Research Quarterly, 36:168-72, May, 1965.
92. Morgan, W. B. "Evaluation of Isometric Strength Gains," Scholastic Coach, 33:29, May, 1964.
93. Müller, E. A., and Theodor Hettinger. "Muskelleistung and Muskeltraining," Arbeitsphysiologie, 15:111-26, October, 1953.
94. Nagle, Francis J., and Thomas G. Bedeckl. "Use of 180 Heart Rate Response as a Measure of Circulo-respiratory Capacity," Research Quarterly, 34:361-69, October, 1963.
95. Pitchford, Keith, and Paul Hamilton. "Isometrics Are

- for Tennis Too," Athletic Journal, 45:36-37, February, 1965.
96. Barick, Laurence G., and Gene L. Larsen. "Observation on Frequency and Intensity of Isometric Muscular Effort in the Development of Static Muscular Strength in Post-Pubescent Males," Research Quarterly, 29:333-41, October, 1958.
 97. Rasch, Philip J. "Relationship Between Maximum Isometric Tension and Maximum Isotonic Elbow Flexion," Research Quarterly, 28:85, March, 1957.
 98. ———, and Laurence E. Morehouse. "Effect of Static and Dynamic Exercise on Muscular Strength and Hypertrophy," Journal of Applied Physiology, 9:29-34, July, 1957.
 99. ———, and William R. Pierson. "Relationship Between Maximum Isometric Tension and Breaking Strength of Forearm," Research Quarterly, 31:534, October, 1960.
 100. Richey, H. "Solution: Isometrics," Athletic Journal, 45:48-49, November, 1964.
 101. Rodahl, K., et al. "Physical Work Capacity," Archives of Environmental Health, 2:499-510, June, 1961.
 102. Royce, Joseph. "Isometric Fatigue Curves in Human Muscles with Normal and Occluded Circulation," Research Quarterly, 29:204, May, 1948.
 103. ———. "Re-evaluation of Isometric Training Methods and Results," Research Quarterly, 35:215, May, 1964.
 104. Ryhming, Irma. "A Modified Harvard Step Test for the Evaluation of Physical Fitness," Arbeitsphysiologie, 15:236, 1954.
 105. Salit, Elizabeth P., and W. W. Tuttle. "The Validity of Heart Rate and Blood Pressure Determinations as Measures of Physical Fitness," Research Quarterly, 15:252-57, October, 1944.
 106. Salter, Nancy. "Effect of Muscle Strength of Maximum Isometric and Isotonic Contraction at Different Repetition Rates," Journal of Physiology, 79:437-43, October, 1955.
 107. Schnebel, W. G., and Edwin R. Elbel. "Reaction of

- Pulse to Successive Periods of Exercise," Journal of Applied Physiology, 4:7-14, July, 1951.
108. Schneider, E. C. "A Cardiovascular Rating as a Measure of Physical Fatigue and Efficiency," Journal of the American Medical Association, 74:507-515, May 29, 1920.
 109. Schwartz, Esar. "Effect of Isometric and Isotonic Exercise on Heart Rate," Research Quarterly, 37:121-25, March, 1966.
 110. Skubic, Vera, and Jean Hodgkins. "Cardiovascular Efficiency Test for Girls and Women," Research Quarterly, 34:191-98, May, 1963.
 111. Slater-Hammel, A. T., and L. K. Butler. "Accuracy in Securing Rates by Palpation," Research Quarterly, 11:18-22, May, 1963.
 112. Sloan, A. W. "A Modified Harvard Step Test for Women," Journal of Applied Physiology, 14:985-86, November, 1959.
 113. _____. "Effect of Training on the Physical Fitness of Women Students," Journal of Applied Physiology, 16:167, January, 1961.
 114. Start, K. B., and J. S. Graham. "The Relationship Between Relative and Absolute Isometric Endurance of Isolated Muscle Groups," Research Quarterly, 35:193-99, May, 1964.
 115. Taddanio, Dominick A., and Peter V. Karpovich. "The Harvard Step Test as a Measure of Endurance in Running," Research Quarterly, 22:381-84, October, 1951.
 116. Taylor, C. "Studies in Exercise Physiology: Effect of Work Load and Training on Heart Rate," American Journal of Physiology, 135:27-42, December, 1941--February, 1942.
 117. Thompson, Clem W. "Comparison of Effects of Isometric and Isotonic Work on Blood Pressure," Research Quarterly, 25:476, December, 1954.
 118. Tuttle, W. W. "The Use of Pulse-Ratio Test for Rating Physical Efficiency," Research Quarterly, 2:89-95, May, 1931.

119. _____, and S. M. Horvath. "Comparison of Effects of Static and Dynamic Work on Blood Pressure and Heart Rate," Journal of Applied Physiology, 10:294-96, March, 1957.
120. Wagner, Berny. "Simple Isometrics," Scholastic Coach, 32:22, December, 1963.
121. Wickstrom, R. L. "An Observation on Isometric Contraction as a Training Technique," Journal of Association for Physical and Mental Rehabilitation, 12:5, September-October, 1958.
122. Wolbers, Charles P., and Frank S. Sills. "Development of Strength in High School Boys by Static Muscular Contraction," Research Quarterly, 27:446-50, December, 1956.

C. UNPUBLISHED MATERIALS

123. Bender, Jay A., et al. "Cardiovascular Response as Related to Isometric and Isotonic Activities." Research study conducted at Southern Illinois University. (Personal correspondence.)
124. Boynton, Bernice. "The Physical Growth of Girls." Ph.D. dissertation, State University of Iowa, Iowa City, 1936. 105 pp. (Microcard.)
125. Carr, Norma June. "The Effect of Isometric Contraction and Progressive Body Conditioning Exercises on Selected Aspects of Physical Fitness and Badminton Achievement of College Women." Unpublished Master's thesis, University of Washington, Seattle, 1962. 132 pp. (Microcard.)
126. Cooper, Leonard Allen. "A Comparison of the Effects of Short Intensive and Prolonged Intensive Exercise Programs on Treadmill Performance and Certain Cardiorespiratory Functions." Unpublished Master's thesis, University of Alberta, Edmonton, 1963. 175 pp. (Microcard.)
127. Day, June I. "A Study of the Reduction of the Waistline of Women by Maximal Isometric Contraction of the Abdominal Wall." Unpublished Master's thesis, Louisiana State University, Baton Rouge, 1957. 47 pp. (Microcard.)

128. Doroschuk, Eugene Valen. "The Relationship of Metabolic, Cardiovascular, and Motor Fitness Tests with Endurance Running of Young Boys." Ph.D dissertation, University of Illinois, Urbana, 1962. 69 pp. (Microcard.)
129. Glad, Harold L. "A Comparison of the Effect of Isometric and Isotonic Exercising upon the Development of Cardiovascular Efficiency." Research study conducted at Gettysburg College. (Personal correspondence.)
130. Holmes, R. A. "The Effects of Various Methods of Training on Endurance and Cardio-vascular Tests." Unpublished Master's thesis, University of Illinois, Urbana, 1958. 73 pp. (Microcard.)
131. King, Louise Chloe. "An Investigation of Effects of Two Training Programs on Selected Cardio-respiratory Variables of College Women." Unpublished Master's thesis, Woman's College of the University of North Carolina, Greensboro, 1962. 120 pp.
132. Milton, George A. "The Effects of Three Programs of Long Distance Running and an Isometric Exercise Program on the Development of Cardio-vascular Efficiency." Paper presented at the 1967 Central District American Association of Health, Physical Education, and Recreation Convention. (Personal correspondence.)
133. Perkins, Gene. "Isometric Contraction as an In-Season Training Program." Unpublished Master's thesis, Baylor University, Waco, Texas, 1963. 98 pp. (Microcard.)
134. Riley, Marie I. "Relationships Between Selected Anthropometric Measurements and Tests of Physical Performance of Girls in Grades One Through Nine." Ph.D. dissertation, Florida State University, Tallahassee, 1962. 125 pp. (Microcard.)
135. Thomas, Judith Carol. "The Effect of Progressive Programs of Exercise Using Exercycle on Development of Cardiorespiratory Endurance of College Women." Unpublished Master's thesis, University of Washington, Seattle, 1963. 82 pp. (Microcard.)
136. Vandine, Dora. "A Comparison of the Effects of

Isometric and Isotonic Exercises on the Reduction of Girth of Glutei and Thigh Muscles." Unpublished Master's thesis, State University of Iowa, Iowa City, 1964. 55 pp.

137. Woodall, A. W. "The Construction and Standardization of a Cardiovascular Test for Girls." Unpublished Master's thesis, Woman's College of the University of North Carolina, Greensboro, 1958. 83 pp.

APPENDIX A
PILOT STUDY

PROCEDURES FOR THE PILOT STUDY

I. SELECTION OF SUBJECTS

A preliminary study was carried out using subjects from a second semester physical education basketball class at the University of North Carolina at Greensboro. This class included freshmen and sophomore women, and it met on Monday and Wednesday of each week. On February 13 the experiment was explained to the class by the writer, and volunteers were solicited with no attempt at randomization. Seventeen volunteers signed up for testing times convenient to their schedules on the evenings of February 15 or February 16 from 6:00-8:00. The sign-up intervals allowed for the testing of no more than two persons in a ten-minute period. The subjects were instructed to wear their gym tunics and tennis shoes and to report to Rosenthal Gymnasium at the scheduled time.

II. FIRST TESTING SESSION

Upon reporting to the gymnasium at the appointed hour, each subject was directed to the graduate dressing room. Only the subject and the writer were present for all measuring. The subject removed her shoes and stepped onto Chattrillon scales, which had been previously calibrated. Her weight was recorded to the nearest half-pound. Moving

to the stadiometer platform, the subject stood erect with her feet centered on tape markings that were six inches apart, and she distributed her body weight evenly. The measurements were then taken and recorded by the writer. Measurements were taken as follows:

Upper arm girth. (27:124) The tape was placed around the dominant upper arm at the place of the greatest girth (over the bulge of the biceps and the triceps). Sufficient tension was exerted to contact the extremity without compression of tissues.

Waist girth. (19:134) The tape was placed, next to the subject's skin, around the waist at the smallest point and held there through a period of inhalation and exhalation. The mean measurement was recorded.

Hip girth. (127) The tape was placed around the subject at the place of the greatest circumference. Attention was given to making certain that the tape was horizontal and that the measurement was read at the side of the subject.

Thigh girth. (27: 6) The tape was placed around the thigh at the point of the greatest circumference.

Calf girth. (6:124) The tape was placed around the maximum circumference of the calf and roughly at right angles to the vertical plane.

Following the taking of measurements, the subject put on her shoes and went to the gymnasium, outside of which she was instructed to sit and wait until her name was called. Two subjects were called in and tested simultaneously. Two previously trained graduate students administered the Clarke Modification of the Harvard Step Test (46), which consisted of stepping on and off an eighteen-inch bench at the rate of thirty steps per minute for four minutes. The stepping exercise was as follows:

Up: Placed one foot on the bench.

Count two: Brought other foot up and straightened back and legs.

Count three: Stepped down with the first foot.

Count four: Stepped down with the other foot to original position.

Uniform instructions (see page 120) were read from a card to the subjects, who were then allowed to practice the steps one or two times. The cadence of 120 beats per minute was set by an electric metronome. (6; 81; 107)

The two subjects stood at opposite ends of a bench specifically built for the step test, and each subject was tested by one of the graduate students. On the signal "ready-go" the subjects began the stepping exercise. If a subject did not maintain the pace set by the metronome, she was stopped by the examiner twenty seconds after she fell off the pace. If the subject reached the point of

fatigue where she could not continue, she stopped herself.

At the completion of the exercise, the subjects immediately sat in chairs that had been placed adjacent to the ends of the bench. The testers timed a sixty-second rest period and then recorded by means of the radial pulse the subject's pulse count for thirty seconds. For the test each examiner had two stop watches; one timed the duration of the exercise, and the other timed the minute-and-a-half recovery period from the moment the subject stopped the stepping exercise.

Each subject's physical efficiency score was calculated by using the following formula (46):

$$\frac{\text{Duration of exercise in seconds} \times 100}{\text{Pulse count from 60 sec. to 90 sec.} \times 5.5} = \text{Physical Efficiency Score}$$

III. EXERCISE SESSIONS

On the basis of the pre-test physical efficiency scores, the subjects were divided statistically into two equated groups: Group 1, which would be the six-second contraction group, and Group 2, the twelve-second contraction group.

At the beginning of the first class period following the pre-test session (February 20), the subjects were informed of their group assignments. The members of the class who did not volunteer for the experiment were also

assigned individually, and the entire class practiced the exercises. Group 1 performed the exercise series while Group 2 practiced basketball. The exercise sequence for both groups was identical except for the length of contraction. Each exercise was to be executed by a contraction, a six-second rest, another contraction, and another six-second rest. Timing was done with a stop watch, and the signals of "contract" and "relax" were given by the writer. When Group 1 was finished, they exchanged positions with Group 2, who followed the same procedure.

At the beginning of the class periods for the next four weeks, or a total of eight exercise periods, each group separately performed its exercises, timed with the stop watch and led by the author. The subjects were asked NOT to perform the exercises outside the class periods in order to assure the greatest control.

IV. EXERCISES

The isometric exercises used for the pilot study were identical for Group 1 and for Group 2, the variable being the length of the contraction. Group 1 contracted for six seconds while Group 2 contracted for a longer period of twelve seconds. The exercises used were the following:

Hips and abdomen. (127; 133) Stand with the weight evenly distributed. Draw in the abdomen as tightly as

possible and at the same time contract the gluteals as tightly as possible.

Abdomen. (91) Lie on the floor, face up, legs extended, hands clasped behind head. Slowly raise the head by bending the neck and continue bending the trunk forward until the shoulders are slightly raised from the floor.

Arms. (4) Stand straight with abdomen pulled in tightly and shoulders relaxed. Raise left arm forward to shoulder level, palms down and elbow slightly bent. Place right hand on inside of left wrist and attempt to bend the left arm toward you, resisting with the right hand. Repeat with the other arm.

Arms. (4) Stand straight with abdomen pulled in tightly. Bend left arm to a right angle, palm down, and place right hand under left wrist. Push downward as hard as possible with left arm but allow no movement to occur. Repeat with the other arm.

Legs. (4) Lie on floor, face up, and draw right knee to the chest as far as possible with the thigh fully flexed and lower leg parallel to the floor. Place a towel around the bottom of the foot and push the leg as hard as possible against the resistance provided by the towel, keeping the head on the floor. Repeat with the other leg.

Upper back and waist. (4; 133) Stand straight with

abdomen pulled in tightly. Grasp a towel with both hands; raise arms overhead and wide apart so that they form a V, palms facing outward. Press sideward with both arms.

V. FINAL TESTING SESSION

The same procedures used in the initial testing session were followed in the final testing session with the following exceptions:

1. A carotid pulse was used instead of a radial pulse since some of the subjects' radial pulses were found to be very faint despite the increased post-exercise rate.
2. Only one subject was tested at a time since the experimenter wished to eliminate the factor of motivation. Competition with the other subject being tested was felt to have exerted an influence during the first testing session.
3. The Skubic-Hodgkins Cardiovascular Efficiency Test for College Women was substituted for the Clarke Test used previously. The rationale behind this decision was based upon the fact that only one of the subjects completed the four minutes of stepping required in the Clarke Test. Since this was a pilot study, the experimenter wished to determine if the Skubic-Hodgkins Test would be more satisfactory for her purposes.

INSTRUCTIONS FOR CARDIOVASCULAR EFFICIENCY TEST

Stand and face the bench. Upon hearing the signal "ready-go," you are to step on and off the bench in this manner:

Count 1: Step up on the bench on either foot.

Count 2: Step up on the other foot.

Count 3: Step down with the first foot.

Count 4: Step down with the other foot.

Straighten your knees completely at the top of the bench.

A metronome will sound the cadence which you are to maintain until you hear the signal "stop." Sit in the chair to recover and after a minute's rest, your pulse rate will be taken. Try it once. Questions?

SAMPLE OF EXERCISE INSTRUCTIONS

Therapeutic Exercises--Isometric Exercises

Beginning on Friday, April 7, and continuing for the next five weeks, you are to perform each of these exercises daily (Saturday and Sunday too). As a member of Experimental Group _____, you are to contract maximally _____ seconds; relax _____ seconds; contract _____ seconds; and relax _____ seconds; and then immediately go on to the next exercise. It is vital for this experiment that the number of seconds be absolutely correct, and you are to exercise in a corridor or somewhere where you can stand before a clock with a sweep second-hand if at all possible. I know that you will all cooperate. So, until May 12, you're on your own---

Good luck! And here's to all of those lost inches!

#1. SIBBING.

APPENDIX B

EXERCISE INSTRUCTIONS AND SCORE CARD

1. Lie on the floor on your back, arms extended and hands clasped behind your neck.
2. Lift your head and shoulders slightly from the floor.
3. Contract; relax; contract; relax.

#2. Back Lifter.

1. Lie on the floor on your back, arms at your sides with the palms down.
2. Lift your pelvis, keeping your head, hands, and heels in contact with the floor.
3. Contract; relax; contract; relax.

#3. Tummy and Hip Tightener.

1. Lie on the floor on your back, arms relaxed at your sides.
2. Contract your gluteal muscles as tightly as possible and at the same time draw in your abdomen as tightly as you can.
3. Contract; relax; contract; relax.

#4. Towel Puller--leg.

1. Lie on the floor on your back; draw right knee to the chest as far as possible with the thigh fully flexed; the lower leg still parallel to the floor.

SAMPLE OF EXERCISE INSTRUCTIONS

Thesis Study--Isometric Exercise

Beginning on Friday, April 7, and continuing for the next five weeks, you are to perform each of these exercises daily (Saturday and Sunday too!). As a member of Experimental Group _____, you are to contract maximally _____ seconds, relax _____ seconds, contract _____ seconds, and relax _____ seconds, and then immediately go on to the next exercise. It is vital for this experiment that the number of seconds be absolutely correct, and you are to exercise in a corridor or somewhere where you can stand before a clock with a sweep second-hand if at all possible. I know that you will all cooperate. So, until May 12, you're on your own----

Good luck! And here's to all of those lost inches!

#1. Sit-up.

1. Lie on the floor, legs extended and hands clasped behind your neck.
2. Slowly raise the head and continue until the shoulders are slightly raised from the floor.
3. Contract, relax, contract, relax.

#2. Back lifter.

1. Lie on the floor on your back, arms at your sides with the palms down.
2. Lift your pelvis, keeping your head, hands, and heels in contact with the floor.
3. Contract, relax, contract, relax.

#3. Tummy and hip tightener.

1. Lie on the floor on your back, arms relaxed at your sides.
2. Contract your gluteal muscles as tightly as possible and at the same time draw in your abdomen as tightly as you can.
3. Contract, relax, contract, relax.

#4. Towel Puller--legs.

1. Lie on the floor on your back, draw right knee to the chest as far as possible with the thigh fully flexed, the lower leg still parallel to the floor.

2. Place the towel around the bottom of the foot and push the leg as hard as possible against the resistance provided by the towel, keeping your head back on the floor.
3. Contract, relax, contract, relax.
4. Repeat with the other leg.

#5. Towel Puller--arms.

1. Stand straight, abdomen pulled in tightly.
2. Grasp the towel with both hands and raise the arms directly overhead straight, palms facing outward.
3. Pull the towel apart with both hands as hard as possible.
4. Contract, relax, contract, relax.

#6. Pusher-Puller.

1. Stand straight, shoulders relaxed, abdomen pulled in tightly.
2. Raise the left arm forward to shoulder level, palm down, elbow slightly bent. Place the right hand on the inside of the left wrist and attempt to bend the left arm toward you, resisting with the right hand.
3. Contract, relax, contract, relax.
4. Repeat this with the other arm.

#7. Cross-Handed Push--sitting.

1. Sit on a chair so that your feet are on the floor.
2. Place the palm of your right hand against the inside of your left knee and the palm of your left hand against the inside of your right knee and push hard against each other.
3. Contract, relax, contract, relax.

SAMPLE OF SCORE CARD

GROUP: _____

NAME: _____

1

2

Date: _____

Weight: _____

ANTHROPOMETRIC
MEASUREMENTS:

Upper arm girth: _____

Waist girth: _____

Hip girth: _____

Thigh girth: _____

Calf girth: _____

HARVARD STEP TEST

Duration: _____

Pulse count: _____

Score: _____

APPENDIX C

ILLUSTRATIONS OF EXERCISES



FIGURE 1
FOOT POSITION FOR MEASUREMENT



FIGURE 2
SIT-UP



FIGURE 1
FOOT POSITION FOR MEASUREMENT



FIGURE 2
SIT-UP



FIGURE 3
BACK LIFTER



FIGURE 4
TUMMY AND HIP TIGHTENER



FIGURE 3
BACK LIFTER



FIGURE 4
TUMMY AND HIP TIGHTENER



FIGURE 5
TOWEL PULLER--LEGS



FIGURE 6
TOWEL PULLER--ARMS



FIGURE 5
TOWEL PULLER--LEGS



FIGURE 6
TOWEL PULLER--ARMS



FIGURE 7

PUSHER-PULLER (SIDE VIEW)



FIGURE 8

PUSHER-PULLER (FRONT VIEW)



FIGURE 7

PUSHER-PULLER (SIDE VIEW)



FIGURE 8

PUSHER-PULLER (FRONT VIEW)



FIGURE 9
CROSS-HANDED PUSH (SIDE VIEW)



FIGURE 10
CROSS-HANDED PUSH (FRONT VIEW)



FIGURE 9
CROSS-HANDED PUSH (SIDE VIEW)



FIGURE 10
CROSS-HANDED PUSH (FRONT VIEW)

TABLE XX

CONVERSION TABLE FOR 1000 GAUSS

ONE INCH = 100

| INCHES | CONVERSION |
|--------|------------|
| 416 | 416 |
| 424 | 424 |
| 432 | 432 |
| 440 | 440 |
| 448 | 448 |
| 456 | 456 |
| 464 | 464 |
| 472 | 472 |
| 480 | 480 |
| 488 | 488 |
| 496 | 496 |
| 504 | 504 |
| 512 | 512 |
| 520 | 520 |
| 528 | 528 |
| 536 | 536 |
| 544 | 544 |
| 552 | 552 |
| 560 | 560 |
| 568 | 568 |
| 576 | 576 |
| 584 | 584 |
| 592 | 592 |
| 600 | 600 |
| 608 | 608 |
| 616 | 616 |
| 624 | 624 |
| 632 | 632 |
| 640 | 640 |
| 648 | 648 |
| 656 | 656 |
| 664 | 664 |
| 672 | 672 |
| 680 | 680 |
| 688 | 688 |
| 696 | 696 |

APPENDIX D

CONVERSION TABLE AND RAW DATA

TABLE XX
CONVERSION TABLE FOR THE TAPE
(One inch = 16)

| Inches | Conversion | Inches | Conversion |
|--------|------------|--------|------------|
| 8 | 128 | 26 | 416 |
| 8½ | 136 | 26½ | 424 |
| 9 | 144 | 27 | 432 |
| 9½ | 152 | 27½ | 440 |
| 10 | 160 | 28 | 448 |
| 10½ | 168 | 28½ | 456 |
| 11 | 176 | 29 | 464 |
| 11½ | 184 | 29½ | 472 |
| 12 | 192 | 30 | 480 |
| 12½ | 200 | 30½ | 488 |
| 13 | 208 | 31 | 496 |
| 13½ | 216 | 31½ | 504 |
| 14 | 224 | 32 | 512 |
| 14½ | 232 | 32½ | 520 |
| 15 | 240 | 33 | 528 |
| 15½ | 248 | 33½ | 536 |
| 16 | 256 | 34 | 544 |
| 16½ | 264 | 34½ | 552 |
| 17 | 272 | 35 | 560 |
| 17½ | 280 | 35½ | 568 |
| 18 | 288 | 36 | 576 |
| 18½ | 296 | 36½ | 584 |
| 19 | 304 | 37 | 592 |
| 19½ | 312 | 37½ | 600 |
| 20 | 320 | 38 | 608 |
| 20½ | 328 | 38½ | 616 |
| 21 | 336 | 39 | 624 |
| 21½ | 344 | 39½ | 632 |
| 22 | 352 | 40 | 640 |
| 22½ | 360 | 40½ | 648 |
| 23 | 368 | 41 | 656 |
| 23½ | 376 | 41½ | 664 |
| 24 | 384 | 42 | 672 |
| 24½ | 392 | 42½ | 680 |
| 25 | 400 | 43 | 688 |
| 25½ | 408 | 43½ | 696 |

TABLE XXI
RAW DATA--CONTROL GROUP

| Subject | C-V Score | | Upper Arm | | Waist | | Hips | | Thigh | | Calf | |
|---------|-----------|-------|-----------|-----|-------|-----|------|-----|-------|-----|------|-----|
| | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 44.77 | 47.27 | 160 | 154 | 376 | 380 | 556 | 552 | 313 | 312 | 208 | 206 |
| 2 | 40.18 | 41.74 | 146 | 140 | 358 | 358 | 550 | 562 | 286 | 286 | 188 | 189 |
| 3 | 25.00 | 29.02 | 146 | 140 | 420 | 420 | 620 | 628 | 366 | 370 | 216 | 216 |
| 4 | 44.64 | 45.91 | 154 | 152 | 386 | 394 | 592 | 592 | 331 | 332 | 216 | 216 |
| 5 | 54.48 | 47.27 | 148 | 150 | 400 | 392 | 578 | 578 | 332 | 330 | 236 | 240 |
| 6 | 36.24 | 42.29 | 156 | 156 | 384 | 384 | 586 | 588 | 338 | 342 | 220 | 220 |
| 7 | 43.43 | 51.84 | 136 | 138 | 374 | 372 | 528 | 530 | 282 | 280 | 180 | 180 |
| 8 | 47.97 | 47.97 | 158 | 156 | 424 | 416 | 608 | 608 | 324 | 320 | 224 | 220 |
| 9 | 27.24 | 27.47 | 164 | 164 | 460 | 464 | 632 | 638 | 360 | 348 | 240 | 236 |
| 10 | 52.69 | 56.39 | 144 | 144 | 412 | 408 | 562 | 560 | 314 | 318 | 192 | 192 |
| 11 | 52.69 | 55.42 | 162 | 160 | 422 | 424 | 582 | 586 | 324 | 334 | 228 | 224 |
| 12 | 57.40 | 53.57 | 152 | 144 | 426 | 424 | 594 | 592 | 326 | 326 | 204 | 204 |
| 13 | 61.81 | 55.42 | 148 | 144 | 384 | 396 | 552 | 548 | 314 | 312 | 188 | 186 |
| 14 | 46.58 | 48.70 | 134 | 134 | 372 | 372 | 544 | 552 | 290 | 288 | 206 | 206 |

TABLE XXII

RAW DATA--EXPERIMENTAL GROUP 1

| Subject | C-V Score | | Upper Arm | | Waist | | Hips | | Thigh | | Calf | |
|---------|-----------|-------|-----------|-----|-------|-----|------|-----|-------|-----|------|-----|
| | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 56.39 | 58.44 | 174 | 172 | 438 | 434 | 626 | 624 | 356 | 352 | 214 | 216 |
| 2 | 66.96 | 68.39 | 164 | 158 | 406 | 390 | 600 | 598 | 332 | 326 | 218 | 212 |
| 3 | 41.21 | 45.27 | 180 | 176 | 472 | 468 | 676 | 668 | 386 | 384 | 250 | 244 |
| 4 | 45.81 | 53.57 | 164 | 162 | 452 | 448 | 588 | 580 | 344 | 336 | 218 | 212 |
| 5 | 52.69 | 56.39 | 140 | 136 | 382 | 376 | 566 | 562 | 318 | 314 | 204 | 204 |
| 6 | 50.45 | 53.57 | 174 | 170 | 408 | 404 | 604 | 600 | 352 | 348 | 214 | 212 |
| 7 | 33.12 | 51.84 | 172 | 168 | 406 | 400 | 624 | 616 | 352 | 344 | 210 | 208 |
| 8 | 50.22 | 51.84 | 156 | 150 | 396 | 386 | 572 | 568 | 316 | 316 | 206 | 202 |
| 9 | 41.74 | 43.44 | 158 | 154 | 410 | 408 | 616 | 608 | 346 | 340 | 212 | 212 |
| 10 | 32.25 | 50.22 | 160 | 158 | 392 | 380 | 564 | 564 | 340 | 340 | 211 | 210 |
| 11 | 47.97 | 47.97 | 170 | 172 | 420 | 424 | 574 | 578 | 346 | 352 | 198 | 194 |
| 12 | 47.27 | 48.70 | 172 | 160 | 394 | 384 | 596 | 590 | 348 | 340 | 236 | 232 |
| 13 | 33.13 | 47.27 | 168 | 164 | 410 | 402 | 608 | 602 | 322 | 320 | 218 | 214 |
| 14 | 45.92 | 49.45 | 170 | 164 | 406 | 400 | 634 | 624 | 360 | 352 | 220 | 216 |

TABLE XXIII

RAW DATA--EXPERIMENTAL GROUP 2

| Subject | C-V Score | | Upper Arm | | Waist | | Hips | | Thigh | | Calf | |
|---------|-----------|-------|-----------|-----|-------|-----|------|-----|-------|-----|------|-----|
| | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 42.29 | 46.75 | 150 | 148 | 384 | 376 | 552 | 544 | 308 | 304 | 196 | 192 |
| 2 | 38.37 | 45.92 | 152 | 148 | 412 | 408 | 594 | 592 | 332 | 328 | 216 | 214 |
| 3 | 60.65 | 63.03 | 138 | 136 | 392 | 388 | 562 | 560 | 304 | 302 | 214 | 214 |
| 4 | 43.96 | 45.92 | 148 | 146 | 394 | 390 | 564 | 560 | 312 | 308 | 208 | 206 |
| 5 | 24.06 | 36.90 | 176 | 176 | 434 | 434 | 638 | 630 | 382 | 378 | 216 | 214 |
| 6 | 45.07 | 51.02 | 160 | 160 | 416 | 416 | 632 | 624 | 348 | 340 | 232 | 228 |
| 7 | 50.22 | 51.84 | 168 | 164 | 402 | 400 | 604 | 602 | 336 | 316 | 226 | 225 |
| 8 | 31.06 | 45.92 | 164 | 160 | 430 | 424 | 648 | 632 | 362 | 356 | 222 | 220 |
| 9 | 31.81 | 44.64 | 164 | 164 | 398 | 396 | 596 | 592 | 348 | 344 | 206 | 204 |
| 10 | 53.90 | 54.48 | 150 | 148 | 388 | 382 | 590 | 590 | 336 | 330 | 200 | 198 |
| 11 | 50.22 | 54.48 | 164 | 166 | 362 | 364 | 532 | 528 | 306 | 306 | 200 | 196 |
| 12 | 28.96 | 41.59 | 180 | 172 | 470 | 460 | 650 | 642 | 360 | 360 | 224 | 224 |
| 13 | 45.92 | 45.92 | 170 | 166 | 420 | 420 | 582 | 580 | 344 | 338 | 222 | 220 |
| 14 | 40.69 | 45.27 | 154 | 154 | 406 | 404 | 574 | 574 | 326 | 326 | 214 | 214 |
| 15 | 20.75 | 37.38 | 184 | 180 | 416 | 404 | 604 | 604 | 356 | 342 | 236 | 228 |
| 16 | 48.05 | 50.22 | 160 | 160 | 424 | 422 | 602 | 598 | 338 | 338 | 220 | 216 |